FOR·THE·INCREASE·AND·DIFFVSION·OF·KNOWLEDGE·AMONG·MEN·
PER ORBEM
SMITHSONIAN·INSTITVTION·WASHINGTON·1846·

ANNUAL REPORT

OF THE

BOARD OF REGENTS

OF THE

SMITHSONIAN INSTITUTION,

SHOWING

THE OPERATIONS, EXPENDITURES, AND CONDITION
OF THE INSTITUTION

FOR

THE YEAR ENDING JUNE 30, 1903.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1904.

LETTER

FROM THE

SECRETARY OF THE SMITHSONIAN INSTITUTION,

ACCOMPANYING

The Annual Report of the Board of Regents of the Institution for the year ending June 30, 1903.

SMITHSONIAN INSTITUTION,
Washington, D. C., May 12, 1904.

To the Congress of the United States:

In accordance with section 5593 of the Revised Statutes of the United States, I have the honor, in behalf of the Board of Regents, to submit to Congress the Annual Report of the operations, expenditures, and condition of the Smithsonian Institution for the year ending June 30, 1903.

I have the honor to be, very respectfully, your obedient servant,

S. P. LANGLEY,
Secretary of the Smithsonian Institution.

Hon. WILLIAM P. FRYE,
President pro tempore of the Senate.

ANNUAL REPORT OF THE SMITHSONIAN INSTITUTION FOR THE YEAR ENDING JUNE 30, 1903.

SUBJECTS.

1. Proceedings of the Board of Regents for the session of January 28, 1903.

2. Report of the executive committee, exhibiting the financial affairs of the Institution, including a statement of the Smithson fund, and receipts and expenditures for the year ending June 30, 1903.

3. Annual report of the Secretary, giving an account of the operations and condition of the Institution for the year ending June 30, 1903, with statistics of exchanges, etc.

4. General appendix, comprising a selection of miscellaneous memoirs of interest to collaborators and correspondents of the Institution, teachers, and others engaged in the promotion of knowledge. These memoirs relate chiefly to the calendar year 1903.

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REPORT OF THE SECRETARY.

GENERAL APPENDIX.

LIST OF PLATES.

THE SMITHSONIAN INSTITUTION.

MEMBERS EX OFFICIO OF THE "ESTABLISHMENT."

Theodore Roosevelt, President of the United States.
(Vacancy), Vice-President of the United States.
Melville W. Fuller, Chief Justice of the United States.
John Hay, Secretary of State.
Leslie M. Shaw, Secretary of the Treasury.
Elihu Root, Secretary of War.
Philander C. Knox, Attorney-General.
Henry C. Payne, Postmaster-General.
William H. Moody, Secretary of the Navy.
Ethan Allen Hitchcock, Secretary of the Interior.
James Wilson, Secretary of Agriculture.
George B. Cortelyou, Secretary of Commerce and Labor.

REGENTS OF THE INSTITUTION.

(List given on the following page.)

OFFICERS OF THE INSTITUTION.

Samuel P. Langley, *Secretary.*
Director of the Institution, and Keeper of the U. S. National Museum.

Richard Rathbun, *Assistant Secretary.*

REGENTS OF THE SMITHSONIAN INSTITUTION.

By the organizing act approved August 10, 1846 (Revised Statutes, Title LXXIII, section 5580), "The business of the Institution shall be conducted at the city of Washington by a Board of Regents, named the Regents of the Smithsonian Institution, to be composed of the Vice-President, the Chief Justice of the United States, three members of the Senate, and three members of the House of Representatives, together with six other persons, other than members of Congress, two of whom shall be resident in the city of Washington and the other four shall be inhabitants of some State, but no two of the same State."

REGENTS FOR THE YEAR ENDING JUNE 30, 1903.

The Chief Justice of the United States:

MELVILLE W. FULLER, elected Chancellor and President of the Board, January 9, 1899.

The Vice-President of the United States (vacancy):

WILLIAM P. FRYE, President pro tempore of the Senate, acting as Regent.

	Term expires.
United States Senators:	
SHELBY M. CULLOM (appointed Mar. 24, 1885, Mar. 28, 1889, Dec. 18, 1895, and Mar. 7, 1901)	Mar. 3, 1907
ORVILLE H. PLATT (appointed Jan. 18, 1899, Feb. 23, 1903)	Mar. 3, 1909
FRANCIS M. COCKRELL (appointed Mar. 7, 1901)	Mar. 3, 1905
Members of the House of Representatives:	
ROBERT R. HITT (appointed Aug. 11, 1893, Jan. 4, 1894, Dec. 20, 1895, Dec. 22, 1897, Jan. 4, 1900, and Dec. 13, 1901)	Dec. 23, 1903
ROBERT ADAMS, Jr. (appointed Dec. 20, 1895, Dec. 22, 1897, Jan. 4, 1900, and Dec. 13, 1901)	Dec. 23, 1903
HUGH A. DINSMORE (appointed Jan. 4, 1900, and Dec. 13, 1901)	Dec. 23, 1903
Citizens of a State:	
JAMES B. ANGELL, of Michigan (appointed Jan. 19, 1887, Jan. 9, 1893, and Jan. 24, 1899)	Jan. 24, 1905
ANDREW D. WHITE, of New York (appointed Feb. 15, 1888, Mar. 19, 1894, and June 2, 1900)	June 2, 1906
RICHARD OLNEY, of Massachusetts (appointed Jan. 24, 1900)	Jan. 24, 1906
GEORGE GRAY, of Delaware (appointed Jan. 14, 1901)	Jan. 14, 1907
Citizens of Washington City:	
JOHN B. HENDERSON (appointed Jan. 26, 1892, and Jan. 24, 1898)	Jan. 24, 1904
ALEXANDER GRAHAM BELL (appointed Jan. 24, 1898)	Jan. 24, 1904

Executive Committee of the Board of Regents.

J. B. Henderson, *Chairman.* Alexander Graham Bell. Robert R. Hitt.

PROCEEDINGS OF THE BOARD OF REGENTS AT THE ANNUAL MEETING HELD JANUARY 28, 1903.

In accordance with a resolution of the Board of Regents adopted January 8, 1890, by which its annual meeting occurs on the fourth Wednesday of each year, the board met to-day at 10 o'clock a. m.

Present: Chief Justice Fuller (Chancellor), in the chair; the Hon. William P. Frye; the Hon. S. M. Cullom; the Hon. O. H. Platt; the Hon. F. M. Cockrell; the Hon. Robert Adams, jr.; the Hon. Hugh A. Dinsmore; the Hon. Richard Olney; the Hon. John B. Henderson; Dr. James B. Angell; Dr. A. Graham Bell, and the Secretary, Mr. S. P. Langley.

EXCUSES FOR NONATTENDANCE.

The Secretary stated that Judge Gray had written that his engagements would prevent his attendance; Doctor White was in Europe, and Mr. Hitt was confined to his house by an indisposition.

READING OF THE MINUTES.

At the suggestion of the Chancellor the Secretary read the minutes of the last meeting in abstract, and there being no objection they were declared approved.

ANNUAL REPORT OF THE SECRETARY.

The Secretary presented his annual report of the operations of the Institution to June 30, 1902.

On motion, the report was accepted.

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE.

Senator Henderson, chairman, presented the report of the committee to June 30, 1902.

On motion, the report was adopted.

ANNUAL REPORT OF THE PERMANENT COMMITTEE.

Senator Henderson, chairman, made the following report in regard to the condition of the various matters under the charge of the committee:

There were no new developments during the year with regard to the Avery fund or the Sprague bequest.

THE HODGKINS FUND.

Progress has been made in the suit of O'Donaghue *v.* Smith. An appeal was taken to the general term from the decision of the trial justice who allowed the verdict in favor of the daughter of Mr. O'Donaghue, who was an infant at the time of partition. The general term affirmed the action of the justice below, which has caused delay. The Smithsonian counsel, Mr. Hackett, is now ready to proceed with the hearing of the case.

During the year the house and lot at Elizabeth, N. J. has been sold to advantage.

THE ANDREWS BEQUEST.

A preliminary contest is now going on before a referee upon the question whether one-half of Mr. Andrews's estate should not go to his heirs by reason of an alleged violation of the statutes of 1860, preventing a testator from giving to a charitable corporation more than one-half of his estate, after payment of debts. Mr. Hackett is of the opinion that the Institution's prospects for success continue fair.

THE REID BEQUEST.

During the year the Institution was supplied with a copy of the will of the late Addison T. Reid, of Brooklyn, N. Y., who died on September 15, 1902. The will provides for the payment of the income upon the property to persons named, and upon their death, for the payment of the principal of the estate, with accumulations, to the Smithsonian Institution, to found a chair in biology in memory of the testator's grandfather, Asher Tunis. The will was admitted to probate by the surrogate of King's County on December 10, 1902. The estate is valued at $10,000.

STATEMENT OF FUNDS USED IN EXPERIMENTS IN MECHANICAL FLIGHT.

On November 9, 1898, the Board of Ordnance and Fortifications of the War Department made an allotment of $25,000 for carrying on experiments in mechanical flight, and on December 16, 1899, supplemented this by another allotment of $25,000. These funds lasted until October 15, 1901. Commencing October 16, 1901, and continuing until June 15, 1902, the sum of $5,565.75 was used in carrying on this work from the special funds received from Dr. Alexander Graham Bell and the late Dr. J. H. Kidder, for researches to be conducted personally by the Secretary.

Since June 16, 1902, expenditures for work in mechanical flight have been made from the Hodgkins fund in accordance with the resolution of the Board of Regents of January 26, 1898; and for this purpose from June 16 to December 31, 1902, the sum of $6,558.61 has been used for continuing these experiments.

RESOLUTION RELATIVE TO INCOME AND EXPENDITURE.

Senator Henderson, as chairman of the executive committee, introduced the following customary resolution:

Resolved, That the income of the Institution for the fiscal year ending June 30, 1904, be appropriated for the service of the Institution, to be expended by the Secretary with the advice of the executive committee, with full discretion on the part of the Secretary as to items.

On motion the resolution was adopted.

REPORT OF SPECIAL COMMITTEE ON NEEDS OF UNITED STATES NATIONAL MUSEUM.

Senator Platt, as chairman of the special committee appointed at the last annual meeting, submitted the following report:

The committee of the Board of Regents of the Smithsonian Institution, appointed in accordance with a resolution of the Board "to represent to Congress the pressing necessity of additional room for the proper exhibition of specimens belonging to the National Museum," have examined the plans prepared under the direction of the Secretary of the Smithsonian Institution in accordance with the provisions of the sundry civil appropriation act approved June 28, 1902.

The committee adopted the following motion:

"That under the limitations of the law the committee hereby report to Congress plan B for a new National Museum building as the best obtainable for the amount mentioned; but in the judgment of the committee the larger plan A is believed to be the one which should be adopted, and we, therefore, ask that Congress shall make the appropriation for it instead of for the smaller plan."

But if an appropriation for the construction of a building upon the larger plan can not be made now, the committee respectfully urge upon Congress an appropriation of $1,500,000 to construct that portion of the completed plan shown in Plan B. They further represent to Congress the fact that collections of the greatest value are in immediate danger of destruction, and are now actually undergoing degeneration in the present unsuitable, unsafe, temporary quarters, and that the erection of a new building is absolutely necessary for the preservation of the national collections.

Respectfully submitted.

O. H. Platt,
S. M. Cullom,
F. M. Cockrell,
R. R. Hitt,
Robt. Adams, jr.,
Hugh A. Dinsmore,

Members of the Special Committee of the Board of Regents of the Smithsonian Institution.

After discussion, on motion of Mr. Adams, it was

Resolved, That the report of the committee be adopted, and that they be instructed to proceed to bring the matter to a conclusion by securing an appropriation.

The Secretary announced the death on September 23, 1902, of Major John W. Powell, Director of the Bureau of Ethnology, and his appointment on October 11, of Mr. William H. Holmes as Chief of the Bureau, and made a statement as to the present status of the Bureau and its future policy.

He spoke of the work of the Zoological Park, of the Bureau of International Exchanges, and of the Astrophysical Observatory. He also spoke of the National Museum's needs, and of the efforts being made to secure a new building. He then gave a brief statement of his connection with the Carnegie Institution.

The Secretary submitted to the Board a proposition to add $25,000 of accumulated interest from the unrestricted funds of the Institution to the permanent fund, and after an explanation, Senator Henderson offered the following resolution:

Resolved, That the Secretary is hereby authorized to deposit in the Treasury of the United States, under the terms of section 5591 of the Revised Statutes, as an addition to the permanent fund of the Institution, the sum of $25,000 from the unexpended balance.

On motion the resolution was adopted.

By resolution of the Board a special committee of five, consisting of the Chancellor, Senators Cullom and Platt, and Representatives Adams and Dinsmore was appointed to consider the question of specifically defining the powers of the executive committee, to report at a special meeting called for March 12, 1903.

A special meeting of the Board of Regents was held on March 12, at 10 o'clock a. m.

Present: Mr. Chief Justice Fuller, Chancellor, in the chair; the Hon. William P. Frye, the Hon. O. H. Platt, the Hon. F. M. Cockrell, the Hon. R. R. Hitt, the Hon. Robert Adams, jr., the Hon. Hugh A. Dinsmore, the Hon. John B. Henderson, the Hon. George Gray, Dr. A. Graham Bell; and the Secretary, Mr. S. P. Langley.

The Secretary read letters from Senator Cullom and Doctor Angell, stating that their engagements prevented their attendance. He had no word from Mr. Olney, who had said, however, at the annual meeting that it would probably be impracticable for him to attend on this occasion. Doctor White was absent in Europe.

The Chancellor reported informally upon the duties heretofore discharged by the executive committee. No definite conclusion had been reached as to the question of defining the powers of that committee, but it was thought desirable that it should hold regular meetings and that the Board of Regents should hold two stated meetings in addition to the annual meeting prescribed by law. It was therefore—

Resolved, That, in addition to the prescribed meeting held on the fourth Wednesday in January, regular meetings of the Board shall be held on the Tuesday after the first Monday in December and on the 6th day of March, unless that date falls on Sunday, when the following Monday shall be substituted.

The special committee was continued, with a request to further pursue the examination of the whole subject and to report at the December meeting.

Senator Platt read the following clause from the sundry civil act, approved March 3, 1903:

Building for National Museum: To enable the Regents of the Smithsonian Institution to commence the erection of a suitable fireproof building with granite fronts, for the use of the National Museum, to be erected on the north side of the Mall, between Ninth and Twelfth streets northwest, substantially in accordance with the Plan A, prepared and submitted to Congress by the Secretary of the Smithsonian Institution under the provisions of the act approved June twenty-eighth, nineteen hundred and two, two hundred and fifty thousand dollars. Said building complete, including heating and ventilating apparatus and elevators, shall cost not to exceed three million five hundred thousand dollars, and a contract or contracts for its completion is hereby authorized to be entered into, subject to appropriations to be made by Congress. The construction shall be in charge of Bernard R. Green, Superintendent of Buildings and Grounds, Library of Congress, who shall make the contracts herein authorized and disburse all appropriations made for the work, and shall receive as full compensation for his services hereunder the sum of two thousand dollars annually in addition to his present salary, to be paid out of said appropriations.

Senator Platt suggested that the Secretary be authorized to represent the Board of Regents in carrying out the provisions of this clause; and, after a very full discussion of the subject, the following resolution was adopted:

Resolved, That the Secretary, with the advice and consent of the Chancellor and the Chairman of the Executive Committee, be authorizod to represent the Board of Regents so far as may be necessary in consultation with Bernard R. Green, to whom the construction and contracts for the new Museum building are committed by Congress in the act making an appropriation for that purpose.

Mr. Bell introduced resolutions providing for appointments under the Institution, which were referred to the special committee already existing.

On the motion of Senator Cockrell, it was—

Resolved, That the Secretary cause to be prepared a compilation of all laws or parts of laws referring to or in any manner affecting the Smithsonian Institution and the Bureaus under its charge, including all appropriations by Congress for its purposes or use.

Referring to previous action of the Board concerning the removal of the remains of James Smithson to this country, Mr. Bell offered to bring them to the United States if the Regents would care for them thereafter, and after remarks the suggestion was accepted that Mr. Bell renew his inquiry at the next meeting.

REPORT OF THE EXECUTIVE COMMITTEE OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION

For the Year ending June 30, 1903.

To the Board of Regents of the Smithsonian Institution:

Your Executive Committee respectfully submits the following report in relation to the funds of the Institution, the appropriations by Congress, and the receipts and expenditures for the Smithsonian Institution, the United States National Museum, the International Exchanges, the Bureau of Ethnology, the National Zoological Park, and the Astrophysical Observatory for the year ending June 30, 1903, and balances of former years:

SMITHSONIAN INSTITUTION.

Condition of the Fund July 1, 1903.

The amount of the bequest of James Smithson deposited in the Treasury of the United States, according to act of Congress of August 10, 1846, was $515,169. To this was added by authority of Congress, February 8, 1867, the residuary legacy of Smithson, savings from income and other sources, to the amount of $134,831.

To this also have been added a bequest from James Hamilton, of Pennsylvania, of $1,000; a bequest of Dr. Simeon Habel, of New York, of $500; the proceeds of the sale of Virginia bonds, $51,500; a gift from Thomas G. Hodgkins, of New York, of $200,000 and $8,000, being a portion of the residuary legacy of Thomas G. Hodgkins, and $1,000, the accumulated interest on the Hamilton bequest, savings from income, $25,000, making in all, as the permanent fund, $937,000.

The Institution also holds the additional sum of $42,000, received upon the death of Thomas G. Hodgkins, in registered West Shore Railroad 4 per cent bonds, which were, by order of this committee, under date of May 18, 1894, placed in the hands of the Secretary of the Institution, to be held by him subject to the conditions of said order.

Statement of receipts and expenditures from July 1, 1902, to June 30, 1903.

RECEIPTS.

Cash on hand July 1, 1901		$81, 120. 91	
Interest on fund July 1, 1902	$27, 360. 00		
Interest on fund January 1, 1903	27, 360. 00		
		54, 720. 00	
Interest to January 1, 1903, on West Shore bonds		1, 680. 00	
			$137, 520. 91
Cash from sales of publications		329. 87	
Cash from repayments, freight, etc		11, 105. 50	
			11, 435. 37
Total receipts			148, 956. 28

EXPENDITURES.

Buildings:			
Repairs, care, and improvements	$3, 964. 85		
Furniture and fixtures	1, 068. 05		
		$5, 032. 90	
General expenses:			
Postage and telegraph	418. 98		
Stationery	1, 289. 00		
Incidentals (fuel, gas, etc.)	4, 567. 34		
Library (books, periodicals, etc.)	3, 073. 58		
Salaries [a]	23, 927. 65		
Gallery of art	251. 38		
Meetings	294. 00		
		33, 821. 93	
Publications and researches:			
Smithsonian contributions	790. 01		
Miscellaneous collections	976. 29		
Reports	2, 710. 09		
Special publications	167. 18		
Researches	3, 438. 50		
Apparatus	1, 550. 14		
Hodgkins fund	14, 247. 48		
		23, 879. 69	
Literary and scientific exchanges		5, 714. 09	
Increase of fund		25, 000. 00	
			93, 448. 61
Balance unexpended June 30, 1903			55, 507. 67

The cash received from the sale of publications, from repayments, freights, and other sources is to be credited to the items of expenditure as follows:

Smithsonian contributions	$65. 55		
Miscellaneous collections	253. 24		
Reports	11. 08		
		$329. 87	
Exchanges		8, 911. 27	
Incidentals		2, 194. 23	
			$11, 435. 37

[a] In addition to the above $23,927.65, paid for salaries under general expenses, $10,748.81 were paid for services, viz, $3,034.68 charged to building account, $483 to furniture and fixtures account, $2,718.67 to researches account, $1,886.67 to library account, $1,353.64 to apparatus account, $242.51 to reports account, and $1,029.64 to Hodgkins fund account.

The net expenditures of the Institution for the year ending June 30, 1903, were therefore $82,013.24, or $11,435.37 less than the gross expenditures, $93,448.61, as above stated.

All moneys received by the Smithsonian Institution from interest, sales, refunding of moneys temporarily advanced, or otherwise, are deposited with the Treasurer of the United States to the credit of the Secretary of the Institution, and all payments are made by his checks on the Treasurer of the United States.

Your committee also presents the following statements in regard to appropriations and expenditures for objects intrusted by Congress to the care of the Smithsonian Institution:

Detailed statement of disbursements from appropriations committed by Congress to the care of the Smithsonian Institution for the fiscal year ending June 30, 1903, and from balances of former years.

INTERNATIONAL EXCHANGES, SMITHSONIAN INSTITUTION, 1903.

RECEIPTS.

Appropriated by Congress for the fiscal year ending June 30, 1903, "for expenses of the system of international exchanges between the United States and foreign countries under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employees and the purchase of necessary books and periodicals" (sundry civil act June 28, 1902)	$26,000.00

DISBURSEMENTS.

[From July 1, 1902, to June 30, 1903.]

Salaries or compensation:		
1 acting curator, 12 months, at $225		$2,700.00
1 chief clerk, 12 months, at $183.33		2,199.96
1 clerk, 12 months, at $150		1,800.00
1 clerk, 12 months, at $125		1,500.00
1 clerk, 12 months, at $108.33		1,299.96
1 clerk, 12 months, at $80		960.00
1 clerk, 12 months, at $55		660.00
1 stenographer, 12 months, at $100		1,200.00
1 packer, 11 months, at $55		605.00
1 workman, 11 months, at $60		660.00
1 messenger, 12 months, at $30		360.00
1 messenger, 12 months, at $30		360.00
1 messenger, 12 months, at $25		300.00
1 agent, 12 months, at $91.66⅔		1,100.00
1 agent, 12 months, at $75		900.00
1 agent, 6 months, at $15		90.00
Total salaries or compensation		16,694.92
General expenses:		
Books	$38.00	
Boxes	1,133.10	
Freight	5,674.15	

General expenses—Continued.			
Lighting	$54.45		
Supplies	155.24		
Stationery	428.00		
		$7,482.94	
Total disbursements			$24,177.86
Balance July 1, 1903			1,822.14

INTERNATIONAL EXCHANGES, SMITHSONIAN INSTITUTION, 1902.

Balance July 1, 1902, as per last report			$1,956.01
Salaries or compensation:			
1 agent, 6 months, at $91.66⅔	$550.00		
1 agent, 6 months, at $50	300.00		
1 agent, 6 months, at $15	90.00		
Total salaries or compensation		$940.00	
General expenses:			
Books	7.50		
Boxes	151.50		
Freight	825.97		
Stationery	13.66		
Supplies	16.50		
		1,015.13	
Total disbursements			1,955.13
Balance July 1, 1903			.88

INTERNATIONAL EXCHANGES, SMITHSONIAN INSTITUTION, 1901.

Balance July 1, 1902, as per last report	$23.55

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund, June 30, 1903.

AMERICAN ETHNOLOGY, SMITHSONIAN INSTITUTION, 1903.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1903, "for continuing ethnological researches among the American Indians, under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employees, and the purchase of necessary books and periodicals, fifty thousand dollars, of which sum not exceeding one thousand five hundred dollars may be used for rent of building" (sundry civil act, June 28, 1902)	$50,000.00

DISBURSEMENTS.

Salaries or compensation:	
1 director, 2½ months 8 days, at $375	$1,037.50
1 chief of bureau, 8 months 17 days, at $375	3,205.65
1 ethnologist in charge, 12 months, at $333.33	3,999.96
1 ethnologist, 12 months, at $200	2,400.00
1 ethnologist, 11 months, at $166.67	1,833.37
1 ethnologist, 12 months, at $166.67	2,000.04
1 ethnologist, 12 months, at $133.33	1,599.96

Salaries or compensation—Continued.

1 ethnologist, 12 months, at $125	$1,500.00		
1 ethnologist, 12 months, at $125	1,500.00		
1 ethnologist, 4 months, at $125	500.00		
1 ethnologic assistant, 6 months, at $100	600.00		
1 assistant ethnologist, 12 months, at $75	900.00		
1 illustrator, 12 months, at $166.67	2,000.04		
1 editor, 12 months, at $100	1,200.00		
1 editorial assistant, 2⅚ months, at $75	212.50		
1 librarian, 6 months 14 days, at $75	483.87		
1 clerk, 3 months, at $125	375.00		
1 clerk, 1 month	100.00		
1 clerk, 12 months, at $100	1,200.00		
1 clerk, 12 months, at $100	1,200.00		
1 clerk, 10 months, at $100	1,000.00		
1 clerk, 12 months, at $75	900.00		
1 messenger, 12 months, at $60	720.00		
1 messenger, 12 months, at $50	600.00		
1 skilled laborer, 12 months, at $60	720.00		
1 laborer, 12 months, at $45	540.00		
Total salaries or compensation		$32,327.89	
General expenses:			
Books and binding	498.67		
Drawings and illustrations	300.90		
Electricity	67.98		
Freight	45.10		
Furniture	96.50		
Manuscript	3,651.70		
Miscellaneous	162.17		
Postage, telegraph, and telephone	102.50		
Rental	1,375.00		
Special services	1,161.00		
Specimens	1,937.00		
Stationery	320.01		
Supplies	345.94		
Traveling and field expenses	4,117,65		
		14,182.12	
Total disbursements			$46,510.01
Balance July 1, 1903			3,489.99

AMERICAN ETHNOLOGY, SMITHSONIAN INSTITUTION, 1902.

Balance July 1, 1902, as per last report	$2,976.18

DISBURSEMENTS.

General expenses:

Books	$142.00
Electricity	31.17
Manuscripts	787.50
Miscellaneous	21.58
Telephones	12.50
Rental	125.00
Special services	116.67

General expenses—Continued.

Specimens	$580.00	
Supplies	26.94	
Travel and field expenses	912.05	
Total disbursements		$2,755.41
Balance July 1, 1903		220.77

AMERICAN ETHNOLOGY, SMITHSONIAN INSTITUTION, 1901.

Balance July 1, 1902, as per last report $1.93

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund, June 30, 1903.

NATIONAL MUSEUM—PRESERVATION OF COLLECTIONS, 1903.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1903, "for continuing the preservation, exhibition, and increase of the collections from the surveying and exploring expeditions of the Government, and from other sources, including salaries or compensation of all necessary employees, one hundred and eighty thousand dollars, of which sum five thousand five hundred dollars may be used for necessary drawings and illustrations for publications of the National Museum, and all other necessary incidental expenses" (sundry civil act, June 28, 1902) $180,000.00

EXPENDITURES.

[July 1, 1902, to June 30, 1903.]

Salaries or compensation	$162,208.04		
Special services	1,100.45		
Total services		$163,308.49	
Miscellaneous:			
Drawings and illustrations	$1,772.99		
Supplies	2,971.09		
Stationery	839.19		
Travel	346.89		
Freight	1,164.15		
Total miscellaneous		7,094.31	
Total expenditures			170,402.80
Balance July 1, 1903, to meet outstanding liabilities			9,597.20

Analysis of expenditures for salaries or compensation.

[July 1, 1902, to June 30, 1903.]

Scientific staff:	
1 assistant secretary, 12 months, at $258.33	$3,099.96
1 head curator, 3 months 14 days, at $291.66	1,006.70
1 head curator (acting), 7 months 16 days, at $291.66	2,197.17
1 head curator, 10 months 57 days, at $291.66	3,461.34
1 head curator, 12 months, at $291.66	3,499.92
1 curator (acting), 16 days, at $200	106.67

Scientific staff—Continued.		
1 curator, 12 months, at $200	$2,400.00	
1 curator, 4 months 14 days, at $200	893.33	
1 curator, 6 months, at $100	600.00	
1 curator, 12 months, at $200	2,400.00	
1 curator, 12 months, at $200	2,400.00	
1 curator, 3 months, at $250	750.00	
1 assistant curator, 12 months, at $150	1,800.00	
1 assistant curator, 12 months, at $150	1,800.00	
1 assistant curator, 16 days, at $133.33	71.11	
1 assistant curator, 12 months, at $150	1,800.00	
1 assistant curator, 11 months 14 days, at $133.33	1,528.85	
1 assistant curator, 2 months, at $150	300.00	
1 assistant curator, 12 months, at $116.66	1,399.92	
1 assistant curator, 12 months, at $125	1,500.00	
1 assistant curator, 11 months 27 days, at $116.66	1,384.87	
1 assistant curator, 12 months, at $116.66	1,399.92	
1 assistant curator, 12 months, at $150	1,800.00	
1 assistant curator, 12 months, at $150	1,800.00	
1 assistant curator, 12 months, at $133.33	1,599.96	
1 second assistant curator, 12 months, at $100	1,200.00	
1 aid, 6 months, at $83.33; 6 months, at $100	1,099.98	
1 aid, 11 months 14 days, at $100	1,146.67	
1 aid, 12 months, at $83.33	999.96	
1 aid, 12 months, at $75	900.00	
1 aid, 4 months, at $60	240.00	
1 aid, 5 months 17 days, at $83.33	462.35	
1 aid, 10 months 48½ days, at $83.33	965.41	
1 aid, 12 months, at $100	1,200.00	
1 aid, 1 month, at $50	50.00	
1 aid, 7 months 54 days, at $83.33	731.16	
1 aid, 12 months, at $100	1,200.00	
1 aid, 12 months, at $50	600.00	
1 aid, 6 months, at $100	600.00	
1 custodian, 2 months, at $150	300.00	
		$52,695.25
Preparators:		
1 photographer, 12 months, at $175	2,100.00	
1 modeler, 12 months, at $100	1,200.00	
1 osteologist, 12 months, at $90	1,080.00	
1 draftsman, 13 days, at $5	65.00	
1 preparator, 4 months 20 days, at $40	186.67	
1 preparator, 12 months, at $60	720.00	
1 preparator, 12 months, at $80	960.00	
1 preparator, 12 months, at $100	1,200.00	
1 preparator, 8 months 33 days, at $70	635.65	
1 preparator, 10 months, at $85; 495 hours, at $0.50	1,097.50	
1 preparator, 10 months 51½ days, at $45	525.80	
1 preparator, 6 months 24 days, at $50; 14 days, at $60	366.71	
1 preparator, 1 month, at $40	40.00	
1 preparator, 12 months, at $75	900.00	
1 preparator, 12 months, at $85	1,020.00	
1 preparator, 5 months 15 days, at $40	219.35	
1 preparator, 11 months 27 days, at $90	1,071.00	

Preparators—Continued:		
1 botanical assistant, 2 months, at $40	$80.00	
1 botanical assistant, 2 months 29 days, at $75	220.16	
1 chief taxidermist, 12 months, at $125	1,500.00	
1 taxidermist, 12 months, at $60	720.00	
1 taxidermist, 12 months, at $100	1,200.00	
		$17,107.84
Clerical staff:		
1 administrative assistant, 12 months, at $291.66	3,499.92	
1 editor, 12 months, at $167	2,004.00	
1 chief of division, 12 months, at $200	2,400.00	
1 registrar, 12 months, at $167	2,004.00	
1 disbursing clerk, 12 months, at $116.67	1,400.04	
1 assistant librarian, 12 months, at $133.33	1,599.96	
1 finance clerk, 12 months, at $125	1,500.00	
1 property clerk (acting), 12 months, at $60	720.00	
1 stenographer, 11 months, at $100	1,100.00	
1 stenographer, 4 months 15 days, at $50	225.00	
1 stenographer, 12 months, at $90	1,080.00	
1 stenographer, 12 months, at $175	2,100.00	
1 stenographer and typewriter, 12 days, at $60	24.00	
1 stenographer and typewriter, 7 days, at $50	11.29	
1 stenographer and typewriter, 6 months 45 days, at $60	450.42	
1 stenographer and typewriter, 12 months, at $83.33	999.96	
1 stenographer and typewriter, 3 months 45 days, at $60; 20 days, at $2	308.90	
1 stenographer and typewriter, 16 days, at $60	32.00	
1 stenographer and typewriter, 12 months, at $50	600.00	
1 stenographer and typewriter, 43 days, at $65	91.84	
1 stenographer and typewriter, 1 month 20 days, at $125	205.65	
1 stenographer and typewriter, 5 months 17 days, at $60	332.90	
1 stenographer and typewriter, 2 months 9 days, at $65	149.50	
1 stenographer and typewriter, 5 months 13 days, at $75	406.45	
1 typewriter, 4 months 14 days, at $45; 2 months 42 days, at $40	339.83	
1 typewriter, 12 months, at $65	780.00	
1 typewriter, 4 months 2 days, at $45	183.00	
1 typewriter, 12 months, at $85	1,020.00	
1 typewriter, 12 months, at $70	840.00	
1 clerk, 12 months, at $100	1,200.00	
1 clerk, 12 months, at $35	420.00	
1 clerk, 15 days, at $60	30.00	
1 clerk, 12 months, at $60	720.00	
1 clerk, 12 months, at $75	900.00	
1 clerk, 2 days, at $55	3.67	
1 clerk, 4 months, at $40; 3 months, at $45	295.00	
1 clerk, 12 months, at $75	900.00	
1 clerk, 12 months, at $75	900.00	
1 clerk, 12 months, at $125	1,500.00	
1 clerk, 12 months, at $100	1,200.00	
1 clerk, 12 months, at $60	720.00	
1 clerk, 4 months, at $83.33	333.32	
1 clerk, 9 months, at $75	675.00	
1 clerk, 12 months, at $60	720.00	

Clerical staff—Continued:		
1 clerk, 11 months 25 days, at $40	$473.33	
1 clerk, 12 months, at $75	900.00	
1 clerk, 12 months, at $60	720.00	
1 clerk, 3 months 37 days, at $40	168.43	
1 clerk, 12 months, at $50	600.00	
1 clerk, 3 months 16 days, at $50	175.81	
1 clerk, 12 months, at $50	600.00	
1 clerk, 9 months, at $40; 3 months, at $50	510.00	
1 clerk, 12 months, at $75	900.00	
1 clerk, 12 months, at $60	720.00	
1 clerk, 12 months, at $115	1,380.00	
1 clerk, 12 months, at $75	900.00	
1 clerk, 6 months, at $125	750.00	
1 clerk, 12 months, at $55	660.00	
1 clerk, 4 months 16½ days, at $40	183.57	
1 clerk, 10 months 29 days, at $100	1,093.55	
1 clerk, 12 months, at $50	600.00	
1 cataloguer, 2 days, at $2	4.00	
1 cataloguer, 30 days, at $40	39.39	
1 cataloguer, 22½ days, at $60	45.00	
1 cataloguer, 3 months 27 days, at $50	198.21	
1 bibliographical assistant, 3 months 18 days, at $83.33	303.56	
		$48,850.50
Buildings and labor:		
1 general foreman, 12 months, at $122.50	1,470.00	
1 foreman, 12 months, at $50	600.00	
1 lieutenant of watch, 12 months, at $70	840.00	
1 watchman, 9 months 75 days, at $55	629.79	
1 watchman, 11 months 29 days, at $60	718.00	
1 watchman, 12 months, at $60	720.00	
1 watchman, 12 months, at $60	720.00	
1 watchman, 12 months, at $60	720.00	
1 watchman, 9 months 72 days, at $55	626.06	
1 watchman, 12 months, at $55	660.00	
1 watchman, 12 months, at $55	660.00	
1 watchman, 12 months, at $60	720.00	
1 watchman, 12 months, at $60	720.00	
1 watchman, 11 months 2½ days, at $60	665.00	
1 watchman, 12 months, at $60	720.00	
1 watchman, 12 months, at $55	660.00	
1 watchman, 5 months 54 days, at $55	370.81	
1 watchman, 10 months 48 days, at $55	636.35	
1 watchman, 12 months, at $55	660.00	
1 watchman, 6 months, at $60	360.00	
1 watchman, 12 months, at $55	660.00	
1 watchman, 1 day, at $2	2.00	
1 watchman, 11 months, at $55	605.00	
1 watchman, 1 day, at $2	2.00	
1 watchman, 5 months, 3 days, at $55	280.32	
1 watchman, 12 months, at $40	480.00	
1 watchman, 12 months, at $55	660.00	
1 watchman, 11 months, 18 days, at $55	638.00	
1 watchman, 12 months, at $55	660.00	

Buildings and labor—Continued.

1 watchman, 5 months 30 days, at $55	$328.23
1 watchman, 11 months 18½ days, at $60	697.00
1 watchman, 12 months, at $65	780.00
1 skilled laborer, 12 months, at $40	480.00
1 skilled laborer, 8 months 36 days, at $60	552.00
1 skilled laborer, 25½ days, at $65	55.25
1 skilled laborer, 10 months 16 days, at $40	420.65
1 skilled laborer, 12 months, at $55	660.00
1 skilled laborer, 1 month	62.50
1 skilled laborer, 10 months, at $40; 2 months, at $50	500.00
1 skilled laborer, 12 months, at $50	600.00
1 workman, 313 days, at $1.50	469.50
1 laborer, 219¼ days, at $1.50	328.88
1 laborer, 29 days, at $1.50	43.50
1 laborer, 12 months, at $45	540.00
1 laborer, 2 days, at $1.25	2.50
1 laborer, 320½ days, at $1.50	480.75
1 laborer, 12 months, at $40	480.00
1 laborer, 3 months 25 days, at $40	152.26
1 laborer, 313½ days, at $1.50	470.25
1 laborer, 208 days, at $1.75	364.01
1 laborer, 25 days, at $1.50	37.50
1 laborer, 313½ days, at $1.50	470.25
1 laborer, 15 days, at $1.50	22.50
1 laborer, 106 days, at $1.50	159.00
1 laborer, 1 day	2.00
1 laborer, 12 months, at $45	540.00
1 laborer, 33 days, at $1.75	57.75
1 laborer, 319¾ days, at $1.50	479.63
1 laborer, 25 days, at $1.50	37.50
1 laborer, 25 days, at $1.50	37.50
1 laborer, 320½ days, at $1.50	480.75
1 laborer, 322½ days, at $1.75	564.38
1 laborer, 344 days, at $1.50	516.00
1 laborer, 227 days, at $1.50	340.50
1 laborer, 12 months, at $35	420.00
1 laborer, 25 days, at $1.50	37.50
1 laborer, 29 days, at $1	29.00
1 laborer, 12 months, at $25	300.00
1 laborer, 143 days, at $1.50	214.50
1 laborer, 6 days, at $1.50	9.00
1 laborer, 6 days, at $1.50	9.00
1 laborer, 1 day, at $2	2.00
1 laborer, 11 months, at $50	550.00
1 laborer, 322¾ days, at $1.50	484.13
1 laborer, 313 days, at $1.50	469.50
1 laborer, 315½ days, at $1.50	473.25
1 laborer, 335½ days, at $1.50	503.25
1 laborer, 1 day, at $2	2.00
1 laborer, 1 day, at $2	2.00
1 laborer, 1 day, at $2	2.00
1 laborer, 1 day, at $2	2.00
1 laborer, 12 months, at $40	480.00

Buildings and labor—Continued.

1 laborer, 12 months, at $40	$480.00	
1 laborer, 313 days, at $1.50	469.50	
1 laborer, 3 months, at $20	60.00	
1 laborer, 3 months, at $40	120.00	
1 laborer, 318 days, at $1.50	477.00	
1 laborer, 23 days, at $1.50	34.50	
1 laborer, 2 months 35 days, at $40	125.46	
1 laborer, 158 days, at $1.50	237.00	
1 laborer, 12 months, at $40	480.00	
1 laborer, 23 days, at $1.50	34.50	
1 laborer, 23 days, at $1.50	34.50	
1 laborer, 26 days, at $1.75	45.50	
1 laborer, 12 days, at $1	12.00	
1 laborer, 319½ days, at $1.50	479.25	
1 laborer, 1 day, at $1	1.00	
1 laborer, 313 days, at $1.50	469.50	
1 laborer, 57 days, at $1.50	85.50	
1 messenger, 12 months, at $20	240.00	
1 messenger, 21 days, at $20; 9 days, at $30	23.00	
1 messenger, 6 months 35½ days, at $20	142.90	
1 messenger, 11 months 21 days, at $30	351.00	
1 messenger, 21 days, at $20	14.00	
1 messenger, 12 months, at $20	240.00	
1 messenger, 11 months 13 days, at $20	228.39	
1 messenger, 12 months, at $35	420.00	
1 messenger, 15 days, at $20	10.00	
1 mail carrier, 9 months, at $40	360.00	
1 attendant, 16½ days, at $1	16.50	
1 attendant, 12 months, at $40	480.00	
1 attendant, 156 days, at $1	156.00	
1 attendant, 341¼ days, at 1.50	511.88	
1 cleaner, 12 months, at $30	360.00	
1 cleaner, 12 months, at $35	420.00	
1 cleaner, 1 month 12 days, at $20	27.74	
1 cleaner, 11 months 29 days, at $30	359.00	
1 cleaner, 12 months, at $30	360.00	
1 cleaner, 12 months, at $30	360.00	
1 cleaner, 11 months 29 days, at $30	359.00	
1 cleaner, 11 months 17 days, at $35	404.83	
		$43,554.45
Total salaries		162,208.04

NATIONAL MUSEUM—PRESERVATION OF COLLECTIONS, 1902.

RECEIPTS.

Balance as per report July 1, 1902	$5,709.78

EXPENDITURES.

[July 1, 1902, to June 30, 1903.]

Salaries or compensation	$15.00	
Special services	439.81	
Total services		$454.81

Miscellaneous:			
Drawings and illustrations	$640.78		
Supplies	3,028.60		
Stationery	909.84		
Travel	101.99		
Freight	415.54		
Total miscellaneous		$5,096.75	
Total expenditure			$5,550.62
Balance July 1, 1903			159.16

Total statement of receipts and expenditures.

[July 1, 1901, to June 30, 1903.]

RECEIPTS.

Appropriation by Congress March 3, 1901	$180,000.00

EXPENDITURES.

[July 1, 1901, to June 30, 1903.]

Salaries or compensation	$161,897.99		
Special services	2,255.36		
Total services		$164,153.35	
Miscellaneous:			
Drawings and illustrations	2,787.83		
Supplies	6,533.99		
Stationery	2,663.02		
Travel	2,021.21		
Freight	1,681.44		
Total miscellaneous		15,687.49	
Total expenditure			179,840.84
Balance July 1, 1903			159.16

NATIONAL MUSEUM—PRESERVATION OF COLLECTIONS, 1901.

RECEIPTS.

Balance as per report July 1, 1902	$74.49

EXPENDITURES.

Special services		$8.00	
Miscellaneous:			
Freight	$39.36		
Supplies	2.25		
Total miscellaneous		41.61	
Total expenditure			49.61
Balance			24.88

Balance carried, under the provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund, June 30, 1903.

Total statement of receipts and expenditures.

[July 1, 1900, to June 30, 1903.]

RECEIPTS.

Appropriation by Congress June 6, 1900			$180,000.00

EXPENDITURES.

[July 1, 1900, to June 30, 1903.]

Salaries or compensation	$159,174.45		
Special services	5,198.14		
Total services		$164,372.59	
Miscellaneous:			
Drawings and illustrations	2,436.30		
Supplies	6,089.10		
Stationery	1,751.99		
Travel	3,490.19		
Freight	1,834.95		
Total miscellaneous		15,602.53	
Total expenditures			179,975.12
Balance carried to surplus fund as above			24.88

NATIONAL MUSEUM—FURNITURE AND FIXTURES, 1903.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1903, "for cases, furniture, fixtures, and appliances required for the exhibition and safe-keeping of the collections of the National Museum, including salaries or compensation of all necessary employees" (sundry civil act June 28, 1902)	$22,500.00

EXPENDITURES.

[July 1, 1902, to June 30, 1903.]

Salaries	$12,342.35	
Special services	14.60	
Total services		$12,356.95
Miscellaneous:		
Cases, storage	2,266.00	
Cases, exhibition	881.00	
Drawers, trays, etc	844.52	
Frames and woodwork	743.91	
Glass	452.04	
Hardware	433.66	
Tools	17.48	
Cloth	37.13	
Lumber	590.79	
Paints, oils, etc	259.62	
Office furniture	1,478.38	
Leather, rubber, cork	265.33	

Miscellaneous—Continued.			
Drawings	$4.00		
Slate	58.80		
Travel	114.15		
Total miscellaneous		$8,446.81	
Total expenditures			$20,803.76
Balance July 1, 1903, to meet outstanding liabilities			1,696.24

Analysis of expenditures for salaries or compensation.

[July 1, 1902, to June 30, 1903.]

1 superintendent, 3 months, at $250	$750.00
1 supervisor of construction, 12 months, at $140	1,680.00
1 clerk, 6 months, at $83.33	499.98
1 shop foreman, 12 months, at $85	1,020.00
1 carpenter, 313 days, at $3	939.00
1 carpenter, 195½ days, at $3	586.50
1 carpenter, 152 days, at $3	456.00
1 carpenter, 114 days, at $3	342.00
1 carpenter, 104 days, at $3	312.00
1 carpenter, 66 days, at $3	198.00
1 carpenter, 27 days, at $3	81.00
1 skilled laborer, 313 days, at $2.25	704.25
1 skilled laborer, 8 months 79½ days, at $65	688.69
1 skilled laborer, 11 months, at $62.50	687.50
1 skilled laborer, 7 months, at $90	630.00
1 skilled laborer, 113 days, at $2.80	316.40
1 skilled laborer, 104 days, at $2.80	291.20
1 skilled laborer, 39 days, at $2.80	109.20
1 skilled laborer, 14 days, at $3.50	49.00
1 skilled laborer, 14 days, at $3.50	49.00
1 skilled laborer, 13 days, at $2.80	36.40
1 skilled laborer, 7 days, at $2.50	17.50
1 skilled laborer, ½ day, at $2.80	1.40
1 painter, 11 months 28½ days, at $75	893.95
1 workman, 314½ days, at $2	629.00
1 painter's assistant, 52 days, at $1.75	91.00
1 laborer, 58 days, at $1.75	101.50
1 laborer, 56 days, at $1.50	84.00
1 laborer, 28½ days, at $1.75	49.88
1 laborer, 26 days, at $1.50	39.00
1 laborer, 6 days, at $1.50	9.00
Total	12,342.35

NATIONAL MUSEUM—FURNITURE AND FIXTURES, 1902.

RECEIPTS.

Balance as per report July 1, 1902	$2,136.15

EXPENDITURES.

[July 1, 1902, to June 30, 1903.]

Miscellaneous:		
Cases, exhibition	$70.00	
Drawers, trays, etc	562.83	
Frames and woodwork	481.69	
Hardware	49.39	
Tools	7.77	
Cloth	34.01	
Lumber	124.69	
Paints, oils, etc	8.80	
Office furniture	778.30	
Plumbing	12.35	
Paper	1.25	
Total miscellaneous		$2,131.08
Balance July 1, 1903		5.07

Total statement of receipts and expenditures.

[July 1, 1901, to June 30, 1903.]

RECEIPTS.

Appropriation by Congress, March 3, 1901	$20,000.00

EXPENDITURES.

[July 1, 1901, to June 30, 1903.]

Salaries or compensation	$11,742.49		
Special services	24.40		
Total services		$11,766.89	
Miscellaneous:			
Cases, storage	$230.00		
Cases, exhibition	70.00		
Drawers, trays, etc	1,088.08		
Frames and woodwork	796.64		
Glass	1,193.21		
Hardware	861.03		
Tools	45.38		
Cloth, cotton, etc	106.05		
Lumber	1,445.21		
Paints, oils, etc	308.48		
Office furniture	1,419.85		
Leather, rubber, cork	305.66		
Drawings	103.00		
Plumbing	201.90		
Paper	52.25		
Flour	1.30		
Total miscellaneous		8,228.04	
Total expenditures			19,994.93
Balance July 1, 1903			5.07

NATIONAL MUSEUM—FURNITURE AND FIXTURES, 1901.

RECEIPTS.

Balance as per report July 1, 1902	$1.89

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund, June 30, 1903.

NATIONAL MUSEUM—HEATING AND LIGHTING, 1903.

RECEIPTS.

Appropriation by Congress for the fiscal year ended June 30, 1903, "for expense of heating, lighting, electrical, telegraphic, and telephonic service for the National Museum (sundry civil act, June 28, 1902)	$18,000.00

EXPENDITURES.

[July 1, 1902, to June 30, 1903.]

Salaries or compensation	$8,224.02		
Special services	34.16		
Total services		$8,258.18	
Miscellaneous:			
Coal and wood	$3,908.11		
Gas	932.70		
Rental of call boxes	90.00		
Electrical supplies	190.21		
Electricity	1,255.05		
Heating supplies	864.74		
Telegrams	38.43		
Telephones	499.95		
Total miscellaneous		7,779.19	
Total expenditures			16,037.37
Balance July 1, 1903			1,962.63

Analysis of expenditures for salaries or compensation.

[July 1, 1902, to June 30, 1903.]

1 superintendent, 2 months, at $250	$500.00
1 engineer, 12 months, at $122.50	1,470.00
1 telephone operator, 6 months, at $45; 6 months, at $50	570.00
1 telephone operator, 31½ days, at $1.50	47.25
1 fireman, 12 months, at $60	720.00
1 fireman, 10 months, at $60	600.00
1 skilled laborer, 306⅝ days, at $3	919.88
1 skilled laborer, 12 months, at $75	900.00
1 skilled laborer, 5 months, at $90	450.00
1 skilled laborer, 17 days, at $3.50	59.50
1 skilled laborer, 17 days, at $3.50	59.50
1 skilled laborer, 13½ days, at $3.50	47.25
1 plumber's assistant, 234½ days, at $2.25	527.63
1 laborer, 320½ days, at $1.50	480.75
1 laborer, 317 days, at $1.50	475.50
1 laborer, 79 days, at $2.25	177.75
1 laborer, 98½ days, at $1.75	172.38
1 laborer, 14½ days, at $1.75	25.63
1 laborer, 12 days, at $1.75	21.00
Total	8,224.02

NATIONAL MUSEUM—HEATING AND LIGHTING, 1902.

RECEIPTS.

Balance as per last report, July 1, 1902			$1,560.43

EXPENDITURES.

[July 1, 1902, to June 30, 1903.]

Special services		$25.00	
Miscellaneous:			
Coal and wood	$5.50		
Gas	78.30		
Rental of call boxes	20.00		
Electrical supplies	652.04		
Electricity	174.61		
Heating supplies	338.55		
Telegrams	42.08		
Telephones	189.83		
Electrical installation supplies	32.92		
Total miscellaneous		1,533.83	
Total expenditures			1,558.83
Balance July 1, 1903			1.60

Total statement of receipts and expenditures.

[July 1, 1901, to June 30, 1903.]

RECEIPTS.

Appropriation by Congress March 3, 1901, including electrical installation, $5,000			$23,000.00

EXPENDITURES.

Salaries or compensation	$8,419.13	
Special services	52.75	
Total services		$8,471.88
Miscellaneous:		
Coal and wood	4,492.02	
Gas	1,357.00	
Rental of call boxes	120.00	
Electrical supplies	969.90	
Electricity	975.41	
Heating supplies	912.63	
Telegrams	44.37	
Telephones	674.77	
Total miscellaneous, regular		9,528.10
Total regular expenditure		17,999.98

ELECTRICAL INSTALLATION.

RECEIPTS.

Appropriation	$5,000.00

EXPENDITURES.

Salaries or compensation	$2,090.48			
Miscellaneous:				
Supplies	2,754.87			
Tools	4.18			
Woodwork	148.89			
Total electrical installation		$4,998.42	$4,998.42	
				$22,998.40
Balance of electric installation		1.58		
Balance of appropriation				1.60

NATIONAL MUSEUM—HEATING AND LIGHTING, 1901.

RECEIPTS.

Balance as per report July 1, 1902	$0.23

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund, June 30, 1903.

NATIONAL MUSEUM—POSTAGE, 1903.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1903, "for postage stamps and foreign postal cards for the National Museum" (sundry civil act, June 28, 1902)	$500.00

EXPENDITURES.

[July 1, 1902, to June 30, 1903.]

Postage stamps and foreign postal cards	500.00

NATIONAL MUSEUM—PRINTING AND BINDING, 1903.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1903, "for the Smithsonian Institution, for printing labels and blanks, and for the Bulletins and Proceedings of the National Museum, the editions of which shall not be less than 3,000 copies, and binding, in half turkey or material not more expensive, scientific books and pamphlets presented to and acquired by the National Museum library" (sundry civil act, June 28, 1902)	$17,000.00

EXPENDITURES.

[July 1, 1902, to June 30, 1903.]

Bulletins of the Museum	$7,791.58	
Proceedings of the Museum	7,467.01	
Labels	479.08	
Blanks and circulars	270.35	
Congressional Record	16.00	
Congressional documents	58.25	
Record books	106.24	
Binding	805.90	
Total expenditures		16,994.41
Balance July 1, 1903		5.59

NATIONAL MUSEUM—RENT OF WORKSHOPS, 1903.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1903, "for rent of workshops and temporary storage quarters for the National Museum" (sundry civil act, June 28, 1902)	$4,400.00

EXPENDITURES.

[July 1, 1902, to June 30, 1903.]

Total expenditures	4,399.92
Balance July 1, 1903	.08

NATIONAL MUSEUM—RENT OF WORKSHOPS, 1902.

Balance as per report July 1, 1902	$0.08
Balance July 1, 1903	.08

NATIONAL MUSEUM—RENT OF WORKSHOPS, 1901.

RECEIPTS.

Balance as per report July 1, 1902	$0.08

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund, June 30, 1903.

NATIONAL MUSEUM—BUILDING REPAIRS, 1903.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1903, "for repairs to buildings, shops, and sheds, National Museum, including all necessary labor and material" (sundry civil act, June 28, 1902)	$15,000.00

EXPENDITURES.

[July 1, 1902, to June 30, 1903.]

Salaries or compensation	$10,167.89		
Special services	299.80		
Total services		$10,467.69	
Miscellaneous:			
Lumber	447.90		
Cement, plaster, gravel, lime, sand, mortar	206.01		
Hardware, tools, etc	264.13		
Paints, oils, glue, brushes	505.70		
Woodwork	85.98		
Skylights and ventilators	428.00		
Glass	84.85		
Cloth, cotton, etc	1.50		
Paper	40.50		
Drawings	35.00		
Slating roof	750.00		
Steel beams	47.77		
Brickwork	106.00		
Total miscellaneous		3,003.34	
Total expenditures			13,471.03
Balance July 1, 1903			1,528.97

Analysis of expenditures for salaries or compensation.

[July 1, 1902, to June 30, 1903.]

1 superintendent, 4 months, at $250	$1,000.00
1 foreman, 12 months, at $85	1,020.00
1 clerk, 6 months, at $100	600.00
1 carpenter, 314 days, at $3	942.00
1 carpenter, 276½ days, at $3	829.50
1 carpenter, 90 days, at $3	270.00
1 carpenter, 16 days, at $3	48.00
1 carpenter, 11 days, at $3	33.00
1 skilled laborer, 8 months 81 days, at $70	746.10
1 skilled laborer, 330¼ days, at $2	660.75
1 skilled laborer, 46½ days, at $2.80; 69 days, at $3	337.20
1 skilled laborer, 37 days, at $2.80; 58 days, at $3	277.60
1 skilled laborer, 67 days, at $3	201.00
1 skilled laborer, 39 days, at $2.80; 25 days, at $3	184.20
1 skilled laborer, 53½ days, at $3	160.50
1 skilled laborer, 16 days, at $2.80; 28 days, at $3	128.80
1 skilled laborer, 40½ days, at $2.80	113.40
1 skilled laborer, 34 days, at $2.80	95.20
1 skilled laborer, 14 days, at $3; 9 days, at $3.50	73.50
1 skilled laborer, 22 days, at $2.80	61.60
1 skilled laborer, 19 days, at $3	57.00
1 skilled laborer, 20 days, at $70 per month	46.67
1 skilled laborer, 16 days, at $2.80	44.80
1 skilled laborer, 14 days, at $2.80	39.20
1 skilled laborer, 12 days, at $2.80	33.60
1 skilled laborer, 11½ days, at $2.80	32.20
1 laborer, 317¼ days, at $1.75	555.19
1 laborer, 282 days, at $1.75	493.51
1 laborer, 324¾ days, at $1.50	488.07
1 laborer, 51½ days, at $1.75	90.13
1 laborer, 34 days, at $1.50	51.00
1 laborer, 27 days, at $1.75	47.25
1 laborer, 27 days, at $1.50	40.50
1 laborer, 13 days, at $1.50	19.50
1 painter's helper, 74 days, at $1.75	129.50
1 messenger, 9 months 12 days, at $20	187.74
1 messenger, 1 month 15 days, at $20	29.68
	10,167.89

NATIONAL MUSEUM—BUILDING REPAIRS, 1902.

RECEIPTS.

Balance as per report July 1, 1902	$1,938.30

EXPENDITURES.

[July 1, 1902, to June 30, 1903.]

Salaries or compensation	$30.00	
Special services	11.25	
Total services		$41.25

Miscellaneous:				
Lumber		$84.27		
Brick, cement, plaster, gravel, lime, sand		58.35		
Hardware and tools		257.21		
Paints, oils, brushes		14.50		
Woodwork		258.74		
Paper		7.50		
Slate		770.40		
Total miscellaneous expenditure			$1,450.97	

New boilers.

Special services	$65.00			
Total services		65.00		
Miscellaneous:				
Brick, stone, cement, lime, gravel, sand	4.00			
Pipe, fittings, etc	286.00			
Hardware and tools	19.00			
Paint	1.80			
Travel	43.05			
Total miscellaneous		353.85		
Total expenditure, new boilers			418.85	
Total expenditures				$1,911.07
Balance July 1, 1903				27.23

NATIONAL MUSEUM—BUILDING REPAIRS, 1901.

RECEIPTS.

Balance as per report July 1, 1902	$0.04

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund, June 30, 1903.

NATIONAL MUSEUM—GALLERIES, 1902.

RECEIPTS.

Balance as per report July 1, 1902	$37.92

EXPENDITURES.

[July 1, 1902, to June 30, 1903.]

Lumber	$19.25	
Cement	17.50	
Total expenditures		36.75
Balance July 1, 1903		1.17

Total statement of receipts and expenditures.

[July 1, 1901, to June 30, 1903.]

RECEIPTS.

Appropriation by Congress March 3, 1901	$5,000.00

EXPENDITURES.

[July 1, 1901, to June 30, 1903.]

Salaries or compensation	$2,404.02		
Special services	3.50		
Total		$2,407.52	
Miscellaneous:			
Hardware, tools, etc	269.61		
Cement, gravel, sand, stone	378.42		
Cloth, cotton	24.28		
Brushes	2.50		
Lumber	133.24		
Steel beams, iron posts, etc	1,440.51		
Woodwork	52.75		
Paper	15.00		
Fireproof partitions	275.00		
Total miscellaneous		2,591.31	
Total expenditures			$4,998.83
Balance July 1, 1903			1.17

NATIONAL MUSEUM—BOOKS, 1903.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1903, "for purchase of books, pamphlets, and periodicals for reference in the National Museum" (sundry civil act, June 28, 1902)	$2,000.00

EXPENDITURES.

[July 1, 1902, to June 30, 1903.]

Total expenditures	1,393.38
Balance July 1, 1903	606.62

NATIONAL MUSEUM—BOOKS, 1902.

RECEIPTS.

Balance as per report July 1, 1902	$1,142.97

EXPENDITURES.

[July 1, 1902, to June 30, 1903.]

Total expenditures	944.70
Balance July 1, 1903	198.27

Total statement of receipts and expenditures.

[July 1, 1901, to June 30, 1903.]

RECEIPTS.

Appropriation by Congress March 3, 1901	$2,000.00

EXPENDITURES.

[July 1, 1901, to June 30, 1903.]

Total expenditures	1,801.73
Balance July 1, 1903	198.27

NATIONAL MUSEUM—BOOKS, 1901.

RECEIPTS.

Balance as per report July 1, 1902	$92.14

EXPENDITURES.

[July 1, 1902, to June 30, 1903.]

Total expenditures	86.74
Balance	5.40

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund, June 30, 1903.

Total statement of receipts and expenditures.

[July 1, 1900, to June 30, 1903.]

RECEIPTS.

Appropriation by Congress June 6, 1900	$2,000.00

EXPENDITURES.

Total expenditures	1,994.60
Balance carried to surplus fund, as above	5.40

NATIONAL MUSEUM—PURCHASE OF SPECIMENS, 1903.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1903, "for purchase of specimens to supply deficiencies in the collections of the National Museum" (sundry civil act, June 28, 1902)	$10,000.00

EXPENDITURES.

[July 1, 1902, to June 30, 1903.]

Total expenditures	5,999.31
Balance July 1, 1903	4,000.69

NATIONAL MUSEUM—PURCHASE OF SPECIMENS, 1902.

RECEIPTS.

Balance as per report July 1, 1902	$2,471.30

EXPENDITURES.

[July 1, 1902, to June 30, 1903.]

Total expenditures	2,416.04
Balance July 1, 1903	55.26

Total statement of receipts and expenditures.

[July 1, 1901, to June 30, 1903.]

RECEIPTS.

Appropriation by Congress March 3, 1901	$10,000.00

EXPENDITURES.

Total expenditures	9,944.74
Balance July 1, 1903	55.26

NATIONAL MUSEUM—PURCHASE OF SPECIMENS, 1901.

RECEIPTS.

Balance as per report July 1, 1902	$72.17

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund, June 30, 1903.

NATIONAL MUSEUM—CONTRIBUTIONS TO NATIONAL HERBARIUM, 1903.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1903, "for printing and publishing the contributions from the United States National Herbarium, the editions of which shall not be less than 3,000 copies, including the preparation of necessary illustrations, proof reading, bibliographical work, and special editorial work, $7,000: *Provided*, That one-half of said copies shall be placed on sale at an advance of 10 per cent over their cost" (sundry civil act, June 28, 1902)		$7,000.00

EXPENDITURES.

[July 1, 1901, to June 30, 1903.]

Editorial assistant, 12 months, at $133.33	$1,599.96	
Artist, 7 months 14 days, at $125	933.33	
Printing 1,200 copies of volume 2	471.30	
Paints, brushes, and drawing material	22.90	
Total expenditures		3,027.49
Balance July 1, 1903		3,972.51

NATIONAL MUSEUM—PLANS FOR ADDITIONAL BUILDING, 1903.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1903, "for the preparation, under the direction of the Secretary of the Smithsonian Institution, of preliminary plans for an additional fireproof, steel-frame, brick, and terra-cotta building, to cost not exceeding $1,500,000 for the United States National Museum, to be erected, when appropriated for, on the Mall between Ninth and Twelfth streets west, said plans when completed to be transmitted by the Secretary of the Smithsonian Institution to Congress" (sundry civil act, June 28, 1902)	$5,000.00

EXPENDITURES.

[July 1, 1902, to June 30, 1903.]

For preparation of plans	4,956.80
Balance July 1, 1903	43.20

ASTROPHYSICAL OBSERVATORY, SMITHSONIAN INSTITUTION, 1903.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1903, "for maintenance of Astrophysical Observatory, under the direction of the Smithsonian Institution, including salaries of assistants, the purchase of necessary books and periodicals, apparatus, printing and publishing results of researches, not exceeding 1,500 copies, repairs and alterations of buildings, and miscellaneous expenses, $15,000" (sundry civil act, June 28, 1902)	$15,000.00

DISBURSEMENTS.

Salaries or compensation:			
1 aid, 3½ months, at $175; 8½ months, at $200	$2,312.50		
1 assistant, 2½ months, at $90	225.00		
1 junior assistant, 3½ months, at $110; 8½ months, at $125	1,447.50		
1 junior assistant, 1½ months, at $75	112.50		
1 photographer assistant, 2 months, at $70	140.00		
1 draftsman, 90 days, at $5	450.00		
1 clerk, 1 month	125.00		
1 stenographer, 11½ months and 4 days, at $100	1,162.90		
1 library cataloguer, ½ month and 16 days, at $40	40.64		
1 instrument maker, 3½ months, at $80; 8½ months, at $90	1,045.00		
1 fireman, 12 months, at $60	720.00		
1 fireman, 2 months, at $60	120.00		
1 laborer, 6 months, at $20; 6 months, at $25	270.00		
1 cleaner, 157 days, at $1	157.00		
1 cleaner, 7½ days, at $1	7.50		
Total salaries or compensation		$8,335.54	
General expenses:			
Apparatus	$2,093.88		
Books and binding	157.09		
Bricks	128.90		
Building repairs	40.65		
Castings	67.40		
Electricity	314.55		
Furniture	9.50		
Freight and hauling	117.92		
Lumber	130.40		
Paints, etc	20.81		
Sand, cement, mortar	386.47		
Special services	1,027.47		
Supplies	532.75		
Stone slabs	218.00		
Telegrams	2.96		
		5,248.75	
Total disbursements			$13,584.29
Balance July 1, 1903			1,415.71

ASTROPHYSICAL OBSERVATORY, SMITHSONIAN INSTITUTION, 1902.

Balance July 1, 1902, as per last report	$2,253.69

DISBURSEMENTS.

General expenses:	
Apparatus	$97.67
Books and binding	328.74
Building repairs	71.71
Castings	5.25
Cement, sand, and brick	12.70

General expenses—Continued.		
Electricity	$69.68	
Furniture	14.50	
Lumber	92.68	
Paints	100.66	
Special services	17.50	
Supplies	119.38	
Total disbursements		$930.47
Balance July 1, 1903		1,323.22

ASTROPHYSICAL OBSERVATORY, SMITHSONIAN INSTITUTION, 1901.

Balance July 1, 1902, as per last report	$0.92

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department, to the credit of the surplus fund, June 30, 1903.

OBSERVATION OF ECLIPSE OF MAY 28, 1900.

Balance July 1, 1902, as per last report	$755.74
Balance July 1, 1903	755.74

NATIONAL ZOOLOGICAL PARK, 1903.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1903, "for continuing the construction of roads, walks, bridges, water supply, sewerage, drainage, and for grading, planting, and otherwise improving the grounds; erecting and repairing buildings and inclosures; care, subsistence, purchase, and transportation of animals, including salaries or compensation of all necessary employees; the purchase of necessary books and periodicals; the printing and publishing of operations, not exceeding 1,500 copies, and general incidental expenses not otherwise provided for, $90,000" (sundry civil act, June 28, 1902)	$90,000.00

DISBURSEMENTS.

Salaries or compensation:	
1 superintendent, 12 months, at $225	$2,700.00
1 property clerk, 12 months, at $150	1,800.00
1 clerk, 12 months, at $110	1,320.00
1 clerk, 12 months, at $110	1,320.00
1 stenographer, 12 months, at $83.33	999.96
1 landscape gardener, 12 months, at $83.33	999.96
1 photographer's assistant, 6 months, at $70	420.00
1 head keeper, 12 months, at $112.50	1,350.00
1 keeper, 12 months, at $60	720.00
1 keeper, 12 months, at $60	720.00
1 keeper, 11 months and 23½ days, at $60	706.32
1 laborer, 4 months, at $50; 1 keeper, 8 months, at $60	680.00
1 keeper, 12 months, at $60	720.00
1 sergeant of watch, 12 months, at $65	780.00
1 watchman, 12 months, at $60	720.00
1 watchman, 12 months, at $55	660.00

Salaries or compensation—Continued.		
1 assistant foreman, 12 months, at $65	$780.00	
1 machinist, 12 months, at $83.33	999.96	
1 assistant blacksmith, 11½ months and 7 days, at $60	704.00	
1 workman, 11½ months and 14½ days, at $60	718.06	
1 workman, 11½ months, at $60	690.00	
1 laborer, 11½ months, at $60	690.00	
1 laborer, 12 months, at $60	720.00	
1 laborer, 12 months, at $55	660.00	
1 laborer, 1½ months and 2 days, at $20	31.29	
Total salaries or compensation		$22,609.55
Miscellaneous:		
Apparatus	165.88	
Buildings	1,000.00	
Building material	687.49	
Drawings	75.00	
Fencing, cage material, etc	4,647.69	
Food	12,761.75	
Freight and transportation of animals	2,115.22	
Fuel	834.07	
Furniture	36.40	
Lumber	1,097.51	
Machinery, tools, etc	738.51	
Miscellaneous supplies	796.36	
Paints, oils, glass, etc	357.45	
Postage, telegraph, and telephones	50.50	
Purchase of animals	1,906.81	
Road material and grading	741.67	
Special services	21.00	
Stationery, books, etc	245.10	
Surveying, plans, etc	1,102.50	
Traveling and field expenses	68.50	
Trees, plants, etc	115.11	
Water supply, etc	356.01	
Total miscellaneous		29,920.53
Wages of mechanics and laborers and hire of teams in constructing buildings and inclosures, laying water pipes, building roads, gutters, and walks, planting trees, and otherwise improving the grounds:		
1 stone mason, 7¼ days, at $3.50	$25.38	
1 carpenter, 28½ days, at $3	85.50	
1 carpenter, 28½ days, at $3	85 50	
1 carpenter, 35 days, at $3	105.00	
1 carpenter, 13 days, at $3	39.00	
1 carpenter, 46 days, at $3	138.00	
1 carpenter, 17 days, at $3	51.00	
1 carpenter, 36 days, at $3	108.00	
1 carpenter, 13 days, at $3	39.00	
1 carpenter, 51¼ days, at $3	153.75	
1 carpenter, 62½ days, at $3	187.50	

Wages of mechanics and laborers and hire of teams in constructing buildings and inclosures, etc.—Continued.

1 carpenter, 313½ days, at $3	$940.50
1 painter, 20⅚ days, at $3	62.50
1 cement finisher, 7¾ days, at $2.80	21.70
1 laborer, 291 days, at $2.50	727.50
1 laborer, 365 days, at $2	730.00
1 laborer, 302 days, at $2	604.00
1 laborer, 350 days, at $2	700.00
1 laborer, 279½ days, at $2	559.00
1 laborer, 365 days, at $1.75	638.75
1 laborer, 290½ days, at $1.75	508.37
1 laborer, 347 days, at $1.75	607.25
1 laborer, 172½ days, at $1.75	301.86
1 laborer, 365 days, at $1.75	638.75
1 laborer, 348 days, at $1.75	609.00
1 laborer, 284 days, at $1.75	497.01
1 laborer, 293¾ days, at $1.75	514.06
1 laborer, 327¼ days, at $1.75	572.69
1 laborer, 361¼ days, at $1.75	632.17
1 laborer, 177 days, at $1.50	265.49
1 laborer, 202 days, at $1.50	302.99
1 laborer, 136¼ days, at $1.50	204.37
1 laborer, 353¾ days, at $1.50	530.62
1 laborer, 71¼ days, at $1.50	106.87
1 laborer, 345 days, at $1.50	517.50
1 laborer, 288 days, at $1.50, and 91 days, at $1.75	591.25
1 laborer, 258½ days, at $1.50	387.75
1 laborer, 295½ days, at $1.50	443.25
1 laborer, 194½ days, at $1.50	291.75
1 laborer, 363½ days, at $1.50	545.25
1 laborer, 62¼ days, at $1.50	93.38
1 laborer, 334 days, at $1.50	501.01
1 laborer, 67¾ days, at $1.50	101.62
1 laborer, 275¾ days, at $1.50	413.62
1 laborer, 148¾ days, at $1.50	223.11
1 laborer, 298¼ days, at $1.50	447.38
1 laborer, 342½ days, at $1.50	513.75
1 laborer, 44¼ days, at $1.50	66.37
1 laborer, 182¼ days, at $1.50	273.37
1 laborer, 128½ days, at $1.50	192.75
1 laborer, 71¾ days, at $1.50	107.62
1 laborer, 251 days, at $1.50	376.50
1 laborer, 163½ days, at $1.50	245.27
1 laborer, 307¾ days, at $1.50	461.62
1 laborer, 116½ days, at $1.50	174.74
1 laborer, 274 days, at $1.50, and 91 days, at $1.75	570.25
1 laborer, 309½ days, at $1.50	464.25
1 laborer, 197 days, at $1.50	295.50
1 laborer, 257¼ days, at $1.50	385.87
1 laborer, 126¾ days, at $1.50	190.12

Wages of mechanics and laborers and hire of teams in constructing buildings and inclosures, etc.—Continued.

1 laborer, 202 days, at $1.50	$302.99
1 laborer, 188 days, at $1.50	282.00
1 laborer, 147 days, at $1.50	220.52
1 laborer, 365¾ days, at $1.50	548.63
1 laborer, ¾ day, at $1.50	1.13
1 laborer, 129¼ days, at $1.50	193.87
1 laborer, 4½ days, at $1.50	6.75
1 laborer, 40¾ days, at $1.50	61.12
1 laborer, 39¾ days, at $1.50	59.62
1 laborer, 37 days, at $1.50	55.50
1 laborer, 39¾ days, at $1.50	59.62
1 laborer, 17¾ days, at $1.50	26.62
1 laborer, 28¼ days, at $1.50	42.37
1 laborer, 12½ days, at $1.50	18.75
1 laborer, 11½ days, at $1.50	17.25
1 laborer, 42 days, at $1.50	63.00
1 laborer, 10 days, at $1.50	15.00
1 laborer, 21 days, at $1.50	31.50
1 laborer, 43¾ days, at $1.50	65.63
1 laborer, 53½ days, at $1.50	80.25
1 laborer, 10½ days, at $1.50	15.75
1 laborer, 57¼ days, at $1.50	85.87
1 laborer, 45¾ days, at $1.50	68.62
1 laborer, 64½ days, at $1.50	96.75
1 laborer, 27¾ days, at $1.50	41.62
1 laborer, 41 days, at $1.50	61.50
1 laborer, 50 days, at $1.50	75.00
1 laborer, 5½ days, at $1.50	8.25
1 laborer, 22 days, at $1.50	33.00
1 laborer, 10½ days, at $1.50	15.75
1 laborer, 10½ days, at $1.50	15.75
1 laborer, 10 days, at $1.50	15.00
1 laborer, 38 days, at $1.50	57.00
1 laborer, 22½ days, at $1.50	33.75
1 laborer, 74¼ days, at $1.50	111.37
1 laborer, 118 days, at $1.50	177.00
1 laborer, 13 days, at $1.50	19.50
1 laborer, 54¼ days, at $1.50	81.37
1 laborer, 59¾ days, at $1.50	89.62
1 laborer, 93¼ days, at $1.50	139.87
1 laborer, 83¾ days, at $1.50	125.63
1 laborer, 62 days, at $1.50	93.00
1 laborer, 3 days, at $1.50	4.50
1 laborer, 174¾ days, at $1.50	262.12
1 laborer, 67¾ days, at $1.50	101.62
1 laborer, 336½ days, at $1.50	504.75
1 laborer, 279 days, at $1.50	418.50
1 laborer, 201½ days, at $1.50, and 76 days, at $1.75	435.24
1 laborer, 349½ days, at $1.25	436.87
1 laborer, 353¼ days, at $1.25	441.56

Wages of mechanics and laborers and hire of teams in constructing buildings and inclosures, etc.—Continued.

1 laborer, 240 days, at $1.25, and 121 days, at $1.50	$481.50		
1 laborer, 366½ days, at $1	366.50		
1 laborer, 80 days, at $1	80.00		
1 laborer, 52 days, at $1	52.00		
1 laborer, 453½ days, at $1	453.50		
1 helper, 312¼ days, at 75 cents	234.18		
1 helper, 365 days, at 75 cents	273.75		
1 helper, 20¼ days, at 50 cents	10.12		
1 helper, 35¼ days, at 75 cents	26.44		
1 water boy, 172¼ days, at 75 cents	129.18		
1 water boy, 14 days, at 75 cents	10.50		
1 water boy, 1 day, at 50 cents	.50		
1 water boy, 148¼ days, at 50 cents	74.12		
1 attendant, 69½ days, at 75 cents	52.13		
1 attendant, 223 days, at 75 cents	167.25		
1 attendant, 1 day, at 75 cents	.75		
1 attendant, 7 days, at 75 cents	5.25		
1 stonebreaker, 4 cubic yards, at 60 cents	2.40		
1 stonebreaker, 12 cubic yards, at 60 cents	7.20		
1 stonebreaker, 83 cubic yards, at 60 cents	49.80		
1 wagon and team, 2¼ days, at $3.50	7.88		
1 wagon and team, 79½ days, at $3.50	278.25		
1 wagon and team, 102¾ days, at $3.50	359.63		
1 wagon and team, 353¼ days, at $3.50	1,236.37		
1 horse and cart, 224¾ days, at $1.75	393.31		
1 horse and cart, ¾ day, at $1.75	1.31		
1 horse and cart, ¾ day, at $1.75	1.31		
1 horse and cart, 231¾ days, at $1.75	405.56		
1 horse and cart, 4 days, at $1.75	7.00		
1 horse, 322 days, at 50 cents	161.01		
Total wages of mechanics, etc		$32,714.88	
Total disbursements			$85,244.96
Balance July 1, 1903			4,755.04

NATIONAL ZOOLOGICAL PARK, SMITHSONIAN INSTITUTION, 1902.

Balance July 1, 1902, as per last report		$5,485.23

DISBURSEMENTS.

General expenses:

Apparatus	$1,160.00	
Building materials	23.25	
Fence and cage materials	229.79	
Food	1,022.47	
Freight	879.73	
Fuel	12.99	
Furniture	18.05	
Lumber	220.36	

General expenses—Continued.

Machinery, tools, etc	$44.53	
Miscellaneous supplies	112.48	
Paints, oils, etc	61.91	
Postage, telegrams, and telephones	72.67	
Purchase of animals	30.12	
Road material and grading	1,166.49	
Stationery, books, etc	65.20	
Surveying, plans, etc	256.25	
Travel and field expenses	41.80	
Trees, plants, etc	35.00	
Water supply, etc	24.88	
Total disbursements		$5,477.97
Balance July 1, 1903		7.26

NATIONAL ZOOLOGICAL PARK, 1901.

Balance July 1, 1902, as per last report	$17.28

Balance carried, under provisions of Revised Statutes, section 3090, by the Treasury Department, to the credit of the surplus fund, June 30, 1903.

ELEPHANT HOUSE, NATIONAL ZOOLOGICAL PARK, 1903.

Appropriation by Congress for the fiscal year ending June 30, 1903, "for the construction of an elephant house, with bathing pools and other accessories, including labor and materials and all necessary incidental expenses, ten thousand dollars, one-half of which sums for the National Zoological Park shall be paid from the revenues of the District of Columbia and the other half from the Treasury of the United States" (sundry civil act June 28, 1902)	$10,000.00

DISBURSEMENTS.

Advertising	$18.15	
Drawings, plans, etc	435.00	
Construction of building and accessories	8,971.83	
Labor, outside of contract	510.62	
Total disbursements		9,935.60
Balance July 1, 1903		64.40

RECAPITULATION.

The total amount of funds administered by the Institution during the year ending June 30, 1903, appears from the foregoing statements and account books to have been as follows:

SMITHSONIAN INSTITUTION.

From balance of last year, July 1, 1902	$81,120.91	
From interest on Smithsonian fund for the year	54,720.00	
From interest on West Shore bonds	1,680.00	
From sales of publications	329.87	
From repayments, freight, etc	11,105.50	
		$148,956.28

APPROPRIATIONS COMMITTED BY CONGRESS TO THE CARE OF THE INSTITUTION.

International exchanges—Smithsonian Institution:		
From balance of 1900–1901	$23.55	
From balance of 1901–2	1,956.01	
From appropriation for 1902–3	26,000.00	
		$27,979.56
American ethnology—Smithsonian Institution:		
From balance of 1900–1901	1.93	
From balance of 1901–2	2,976.18	
From appropriation for 1902–3	50,000.00	
		52,978.11
Preservation of collections—National Museum:		
From balance of 1900–1901	74.49	
From balance of 1901–2	5,709.78	
From appropriation for 1902–3	180,000.00	
		185,784.27
Furniture and fixtures—National Museum:		
From balance of 1900–1901	1.89	
From balance of 1901–2	2,136.15	
From appropriation for 1902–3	22,500.00	
		24,638.04
Heating and lighting—National Museum:		
From balance of 1900–1901	0.23	
From balance of 1901–2	1,560.43	
From appropriation for 1902–3	18,000.00	
		19,560.66
Postage—National Museum:		
From appropriation for 1902–3		500.00
Printing and binding—National Museum:		
From appropriation for 1902–3		17,000.00
Rent of workshops—National Museum:		
From balance of 1900–1901	$0.08	
From balance of 1901–2	.08	
From appropriation for 1902–3	4,400.00	
		4,400.16
Building repairs—National Museum:		
From balance of 1900–1901	.04	
From balance of 1901–2	1,938.30	
From appropriation for 1902–3	15,000.00	
		16,938.34
Galleries—National Museum:		
From balance of 1901–2		37.92
Books—National Museum:		
From balance of 1900–1901	$92.14	
From balance of 1901–2	1,142.97	
From appropriation for 1902–3	2,000.00	
		3,235.11
Purchase of specimens—National Museum:		
From balance of 1900–1	72.17	
From balance of 1901–2	2,471.30	
From appropriation for 1902–3	10,000.00	
		12,543.47
Contributions to National Herbarium—National Museum:		
From appropriation for 1902–3		7,000.00
Plans for additional building—National Museum:		
From appropriation for 1903		5,000.00

Astrophysical Observatory—Smithsonian Institution:		
From balance of 1900–1901	$0.92	
From balance of 1901–2	2,253.69	
From appropriation for 1902–3	15,000.00	
		$17,254.61
Observation of eclipse of May 28, 1900:		
From balance July 1, 1902		755.74
National Zoological Park:		
From balance of 1900–1901	$17.28	
From balance of 1901–2	5,485.23	
From appropriation for 1902–3	90,000.00	
		95,502.51

SUMMARY.

Smithsonian Institution	148,956.28	
Exchanges	27,979.56	
Ethnology	52,978.11	
Preservation of collections	185,784.27	
Furniture and fixtures	24,638.04	
Heating and lighting	19,560.66	
Postage	500.00	
Printing and binding	17,000.00	
Rent of workshops	4,400.16	
Building repairs	16,938.34	
Galleries	37.92	
Books	3,235.11	
Purchase of specimens	12,543.47	
Contributions to National Herbarium	7,000.00	
Plans for additional building	5,000.00	
Astrophysical Observatory	17,254.61	
Observation of eclipse	755.74	
National Park	95,502.51	
		640,064.78

The committee has examined the vouchers for payment from the Smithsonian income during the year ending June 30, 1903, each of which bears the approval of the Secretary or, in his absence, of the Acting Secretary, and a certificate that the materials and services charged were applied to the purposes of the institution.

The quarterly accounts current, the vouchers, and journals have been examined and found correct.

Statement of regular income from the Smithsonian fund available for use in the year ending June 30, 1904.

Balance July 1, 1903		$55,507.67
Interest due and receivable July 1, 1903	$27,964.17	
Interest due and receivable January 1, 1904	28,110.00	
Interest, West Shore Railroad bonds, due July 1, 1903	840.00	
Interest, West Shore Railroad bonds, due January 1, 1904	840.00	
		57,754.17
Total available for year ending June 30, 1904		113,261.84

Respectfully submitted.

J. B. HENDERSON,
ALEXANDER GRAHAM BELL.
ROBERT R. HITT.
Executive Committee.

WASHINGTON, D. C., *January 25, 1904.*

ACTS AND RESOLUTIONS OF CONGRESS RELATIVE TO THE SMITHSONIAN INSTITUTION, ETC.

[Continued from previous Reports.]

[Fifty-seventh Congress, first session.]

SMITHSONIAN INSTITUTION.

Smithsonian Deposit [Library of Congress].—For custodian, one thousand five hundred dollars; one assistant, one thousand two hundred dollars; one messenger, seven hundred and twenty dollars; one messenger boy, three hundred and sixty dollars; in all, three thousand seven hundred and eighty dollars. (Approved April 28, 1902; Statutes, XXXII, 130.)

Exchange of Public Documents [Library of Congress].—For expenses of exchanging public documents for the publications of foreign governments, one thousand eight hundred dollars. (Approved April 28, 1902; Statutes, XXXII, 131.)

INTERNATIONAL EXCHANGES.

International Exchanges.—For expenses of the system of international exchanges between the United States and foreign countries, under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employees, and the purchase of necessary books and periodicals, twenty-six thousand dollars. (Approved June 28, 1902; Statutes, XXXII, 439.)

Naval Observatory.—For repairs to buildings, fixtures, and fences, furniture, gas, chemicals and stationery, freight (including transmission of public documents through the Smithsonian exchange), foreign postage and expressage, plants, fertilizers, and all contingent expenses, two thousand five hundred dollars. (Approved April 28, 1902; Statutes, XXXII, 155.)

Geological Survey.—For the purchase of necessary books for the library, including directories and professional and scientific periodicals needed for statistical purposes, and not exceeding four thousand dollars for the payment for the transmission of public documents through the Smithsonian exchange, six thousand dollars: *Provided*, That the purchase of professional and scientific books and period-

icals needed for statistical purposes hereafter by the scientific divisions of the United States Geological Survey is hereby authorized to be made and paid for out of appropriations made for the said Survey. (Approved June 28, 1902; Statutes, XXXII, 455.)

BUREAU OF AMERICAN ETHNOLOGY.

For continuing ethnological researches among the American Indians under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employees and the purchase of necessary books and periodicals, fifty thousand dollars, of which sum not exceeding one thousand five hundred dollars may be used for rent of building. (Approved June 28, 1902; Statutes, XXXII, 439.)

For North American Ethnology, Smithsonian Institution, three dollars and thirty cents. (Approved July 1, 1902; Statutes, XXXII, 585.)

ASTROPHYSICAL OBSERVATORY.

For maintenance of Astrophysical Observatory, under the direction of the Smithsonian Institution, including salaries of assistants, the purchase of necessary books and periodicals, apparatus, printing and publishing results of researches, not exceeding one thousand five hundred copies, repairs and alterations of buildings, and miscellaneous expenses, fifteen thousand dollars. (Approved June 28, 1902; Statutes, XXXII, 439.)

NATIONAL MUSEUM.

For cases, furniture, fixtures, and appliances required for the exhibition and safe-keeping of the collections of the National Museum, including salaries or compensation of all necessary employees, twenty-two thousand five hundred dollars.

For expense of heating, lighting, electrical, telegraphic, and telephonic service for the National Museum, eighteen thousand dollars.

For continuing the preservation, exhibition, and increase of the collections from the surveying and exploring expeditions of the Government, and from other sources, including salaries or compensation of all necessary employees, one hundred and eighty thousand dollars, of which sum five thousand five hundred dollars may be used for necessary drawings and illustrations for publications of the National Museum; and all other necessary incidental expenses.

For purchase of specimens to supply deficiencies in the collections of the National Museum, ten thousand dollars.

For purchase of books, pamphlets, and periodicals for reference in the National Museum, two thousand dollars.

For repairs to buildings, shops, and sheds, National Museum, including all necessary labor and material, fifteen thousand dollars.

For rent of workshops and temporary storage quarters for the National Museum, four thousand four hundred dollars.

For postage stamps and foreign postal cards for the National Museum, five hundred dollars.

For printing and publishing the contributions from the United States National Herbarium, the editions of which shall not be less than three thousand copies, including the preparation of necessary illustrations, proof reading, bibliographical work, and special editorial work, seven thousand dollars: *Provided*, That one-half of said copies shall be placed on sale at an advance of ten per centum over their cost.

For the preparation, under the direction of the Secretary of the Smithsonian Institution, of preliminary plans for an additional fire-proof steel-frame brick-and-terra-cotta building, to cost not exceeding one million five hundred thousand dollars, for the United States National Museum, to be erected when appropriated for, on the Mall, between Ninth and Twelfth streets west, said plans when completed to be transmitted by the Secretary of the Smithsonian Institution to Congress, five thousand dollars. (Approved June 28, 1902; Statutes, XXXII, 439–440.)

For preservation of collections, National Museum, eighty-one dollars and twenty-one cents. (Approved February 14, 1902; Statutes, XXXII, 28.)

For the Smithsonian Institution, for printing labels and blanks, and for the "Bulletins" and "Proceedings" of the National Museum, the editions of which shall not be less than three thousand copies, and binding, in half turkey, or material not more expensive, scientific books and pamphlets presented to and acquired by the National Museum Library, seventeen thousand dollars. (Approved June 28, 1902; Statutes, XXXII, 480.)

NATIONAL ZOOLOGICAL PARK.

For continuing the construction of roads, walks, bridges, water supply, sewerage and drainage; and for grading, planting, and otherwise improving the grounds; erecting and repairing buildings and inclosures; care, subsistence, purchase, and transportation of animals, including salaries or compensation of all necessary employees; the purchase of necessary books and periodicals, the printing and publishing of operations, not exceeding one thousand five hundred copies, and general incidental expenses not otherwise provided for, ninety thousand dollars.

For the construction of an elephant house, with bathing pools and other accessories, including labor and materials and all necessary incidental expenses, ten thousand dollars; one-half of which sums for

the National Zoological Park shall be paid from the revenues of the District of Columbia and the other half from the Treasury of the United States. (Approved June 28, 1902; Statutes, XXXII, 440.)

For National Zoological Park, thirty-seven cents. (Approved July 1, 1902; Statutes, XXXII, 585.)

FIFTY-SEVENTH CONGRESS, SECOND SESSION. REPRINTED FROM 1902 REPORT.

SMITHSONIAN INSTITUTION.

Smithsonian Deposit [Library of Congress].—For custodian, one thousand five hundred dollars; one assistant, one thousand two hundred dollars; one messenger, seven hundred and twenty dollars; one messenger boy, three hundred and sixty dollars; in all, three thousand seven hundred and eighty dollars. (Approved February 25, 1903; Statutes, XXXII, 864.)

Exchange of Public Documents [Library of Congress].—For expenses of exchanging public documents for the publications of foreign governments, one thousand eight hundred dollars. (Approved February 25, 1903; Statutes, XXXII, 865.)

NATIONAL MUSEUM.

For cases, furniture, fixtures, and appliances required for the exhibition and safe-keeping of the collections of the National Museum, including salaries or compensation of all necessary employees, twenty-two thousand five hundred dollars.

For expense of heating, lighting, electrical, telegraphic, and telephonic service for the National Museum, eighteen thousand dollars.

For continuing the preservation, exhibition, and increase of the collections from the surveying and exploring expeditions of the Government, and from other sources, including salaries or compensation of all necessary employees, one hundred and eighty thousand dollars, of which sum five thousand five hundred dollars may be used for necessary drawings and illustrations for publications of the National Museum, and all other necessary incidental expenses.

For purchase of specimens to supply deficiencies in the collections of the National Museum, ten thousand dollars.

For purchase of books, pamphlets, and periodicals for reference in the National Museum, two thousand dollars.

For repairs to buildings, shops, and sheds, National Museum, including all necessary labor and material, fifteen thousand dollars.

For rent of workshops and temporary storage quarters for the National Museum, four thousand four hundred dollars.

For postage stamps and foreign postal cards for the National Museum, five hundred dollars. (Approved March 3, 1903; Statutes, XXXII, 1101, 1102.)

Building for National Museum: To enable the Regents of the Smithsonian Institution to commence the erection of a suitable fire-proof building with granite fronts, for the use of the National Museum, to be erected on the north side of the Mall, between Ninth and Twelfth streets northwest, substantially in accordance with the Plan A, prepared and submitted to Congress by the secretary of the Smithsonian Institution under the provisions of the act approved June twenty-eighth, nineteen hundred and two, two hundred and fifty thousand dollars. Said building complete, including heating and ventilating apparatus and elevators, shall cost not to exceed three million five hundred thousand dollars, and a contract or contracts for its completion is hereby authorized to be entered into subject to appropriations to be made by Congress. The construction shall be in charge of Bernard R. Green, superintendent of Buildings and Grounds, Library of Congress, who shall make the contracts herein authorized and disburse all appropriations made for the work, and shall receive as full compensation for his services hereunder the sum of two thousand dollars annually in addition to his present salary, to be paid out of said appropriations. (Approved March 3, 1903; Statutes, XXXII, 1102.)

For the Smithsonian Institution, for printing labels and blanks, and for the "Bulletins" and "Proceedings" of the National Museum, the editions of which shall not be less than three thousand copies, and binding, in half turkey, or material not more expensive, scientific books and pamphlets presented to and acquired by the National Museum Library, seventeen thousand dollars. (Approved March 3, 1903; Statutes, XXXII, 1146.)

For preservation of collections, National Museum, sixty cents. (Approved March 3, 1903; Statutes, XXXII, 1075.)

INTERNATIONAL EXCHANGES.

For expenses of the system of international exchanges between the United States and foreign countries, under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employees, and the purchase of necessary books and periodicals, twenty-six thousand dollars. (Approved March 3, 1903; Statutes XXXII, 1101.)

Geological Survey.—For the purchase of necessary books for the library, including directories and professional and scientific periodicals needed for statistical purposes, not to exceed two thousand dollars, and the payment for the transmission of public documents through the Smithsonian exchange, four thousand dollars; in all, six thousand dollars. (Approved March 3, 1903; Statutes, XXXII, 1118.)

Naval Observatory.—For repairs to buildings, fixtures, and fences, furniture, gas, chemicals, and stationery, freight (including transmission of public documents through the Smithsonian exchange), foreign postage, and expressage, plants, fertilizers, and all contingent expenses, two thousand five hundred dollars. (Approved February 25, 1903; Statutes, XXXII, 889.)

BUREAU OF AMERICAN ETHNOLOGY.

For continuing ethnological researches among the American Indians, under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employees and the purchase of necessary books and periodicals, forty thousand dollars, of which sum not exceeding one thousand five hundred dollars may be used for rent of building. (Approved March 3, 1903; Statutes, XXXII, 1101.)

NATIONAL ZOOLOGICAL PARK.

For continuing the construction of roads, walks, bridges, water supply, sewerage and drainage; and for grading, planting, and otherwise improving the grounds; erecting and repairing buildings and inclosures; care, subsistence, purchase, and transportation of animals; including salaries or compensation of all necessary employees, the purchase of necessary books and periodicals, the printing and publishing of operations, not exceeding one thousand five hundred copies, and general incidental expenses not otherwise provided for, ninety-five thousand dollars; one-half of which sum shall be paid from the revenues of the District of Columbia and the other half from the Treasury of the United States. (Approved March 3, 1903; Statutes, XXXII, 1102.)

For Adams Mill road, Columbia road to Zoo, grade and improve, seven thousand dollars. (Approved March 3, 1903; Statutes, XXXII, 963.)

That in order to more fully carry out the intent of the provision in the appropriation act approved July first, nineteen hundred and two, providing for the expenses of the government of the District of Columbia, authorizing the readjustment of the lines of the streets on the east side of the Zoological Park, the Commissioners of the District of Columbia be, and they are hereby, authorized to use as a highway so much of the Zoological Park as lies within a proposed street on the east side of said Zoological Park between Kenyon street and Klingle road, the bounds of said street being located as follows: The east building line to be distant fifteen feet from the present improved thirty-foot roadway and the west line to be distant forty-five feet from the present improved thirty-foot roadway. (Approved March 3, 1903; Statutes, XXXII, 963.)

ASTROPHYSICAL OBSERVATORY.

For maintenance of Astrophysical Observatory, under the direction of the Smithsonian Institution, including salaries of assistants, the purchase of necessary books and periodicals, apparatus, making necessary observations in high altitudes, printing and publishing results of researches, not exceeding one thousand five hundred copies, repairs and alterations of buildings and miscellaneous expenses, fifteen thousand dollars. (Approved March 3, 1903; Statutes, XXXII, 1101.)

ILLUSTRATIONS IN GOVERNMENT DOCUMENTS.

That no part of the appropriations herein made for printing and binding shall be used for any illustration, engraving, or photograph, in any document or report ordered printed by Congress unless the order to print expressly authorizes the same, nor in any document or report of any Executive Department or other Government establishment until the head of the Executive Department or Government establishment shall certify in the letter transmitting such report that the illustration is necessary and relates entirely to the transaction of public business. (Sundry civil act, approved March 3, 1903; Statutes, XXXII, 1147.)

REPORT

OF

S. P. LANGLEY,

SECRETARY OF THE SMITHSONIAN INSTITUTION,

FOR THE YEAR ENDING JUNE 30, 1903.

To the Board of Regents of the Smithsonian Institution.

GENTLEMEN: I have the honor to present herewith my report, showing the operations of the Institution during the year ending June 30, 1903, including the work placed under its direction by Congress in the United States National Museum, the Bureau of American Ethnology, the International Exchanges, the National Zoological Park, and the Astrophysical Observatory.

Following the precedent of several years, there is given, in the body of this report, a general account of the affairs of the Institution and its bureaus, while the appendix presents more detailed statements by the persons in direct charge of the different branches of the work. Independently of this, the operations of the National Museum are fully treated in a separate volume of the Smithsonian Report, and the Report of the Bureau of American Ethnology constitutes a volume prepared under the supervision of the Chief of that Bureau.

THE SMITHSONIAN INSTITUTION.

THE ESTABLISHMENT.

By act of Congress approved August 10, 1846, the Smithsonian Institution was created an Establishment. Its statutory members are the President, the Vice-President, the Chief Justice of the United States, and the heads of the Executive Departments. The prerogative of the Establishment is "the supervision of the affairs of the Institution and the advice and the instruction of the Board of Regents."

A vacancy continues to exist in the Establishment caused by the succession to the Presidency of Vice-President Roosevelt. By the organization of the Department of Commerce and Labor its Secretary has become a member of the Establishment.

As organized on June 30, 1903, the Establishment consisted of the following ex officio members:

Theodore Roosevelt, *President of the United States.*
(Vacancy), *Vice-President of the United States.*
Melville W. Fuller, *Chief Justice of the United States.*
John Hay, *Secretary of State.*
Leslie M. Shaw, *Secretary of the Treasury.*
Elihu Root, *Secretary of War.*
Philander C. Knox, *Attorney-General.*
Henry C. Payne, *Postmaster-General.*
William H. Moody, *Secretary of the Navy.*
Ethan Allen Hitchcock, *Secretary of the Interior.*
James Wilson, *Secretary of Agriculture.*
George B. Cortelyou, *Secretary of Commerce and Labor.*

BOARD OF REGENTS.

The Board of Regents consists of the Vice-President and the Chief Justice of the United States as ex officio members, three members of the Senate, three members of the House of Representatives, and six citizens, "two of whom shall be residents of the city of Washington and the other four shall be inhabitants of some State, but no two of them of the same State."

In accordance with a resolution of the Board of Regents adopted January 8, 1890, by which its annual meeting occurs on the fourth Wednesday of each year, the Board met on January 28, 1903, at 10 o'clock a. m.

The following is an abstract of its proceedings, which will be found in detail in the annual report of the Board to Congress:

The Secretary presented his annual report of the operations of the Institution and its several dependencies for the fiscal year ending June 30, 1902, and the Board adopted the annual report of the executive committee to the same date, showing in detail the financial condition of the Institution. The usual resolution relative to income and expenditure was adopted.

Senator Henderson, chairman of the permanent committee, reported upon the expenditures incurred by the Secretary under the authority of the Board of Regents in continuing his experiments on mechanical flight. Statements were made in regard to the proposed bequest of Addison T. Reid; also concerning the will of Wallace C. Andrews and the status of the residuary legacy under the Hodgkins will.

Senator Platt, chairman of the special committee, appointed in accordance with a resolution of the Board—

"to represent to Congress the pressing necessity of additional room for the proper exhibition of specimens belonging to the National Museum"—

reported that the committee had examined the plans prepared under the direction of the Secretary, as provided in the sundry civil act of June 28, 1902, and recommended that if an appropriation for the entire new building could not be made now the committee would respectfully urge upon Congress an appropriation of $1,500,000 to construct a portion of the completed plan. The committee further urged that Congress be advised of the fact that collections of the greatest value are in immediate danger of destruction, and are now actually undergoing degeneration in the present unsuitable, unsafe, temporary quarters, and that the erection of a new building is absolutely necessary for the preservation of the national collections. The members of the committee, in addition to the chairman, were Senators Cullom and Cockrell and Representatives Hitt, Adams, and Dinsmore. The report of the committee was adopted and they were instructed to bring the matter to a conclusion by securing an appropriation.

The Secretary announced to the Board the death, on September 23, 1902, of Maj. J. W. Powell, of the Bureau of Ethnology, and the appointment on October 11 of Mr. William H. Holmes, and made a statement as to the status of the Bureau and its future policy.

On motion of Senator Henderson, the Secretary was—

"authorized to deposit in the Treasury of the United States, under the terms of section 5591 of the Revised Statutes, as an addition to the permanent fund of the Institution, the sum of $25,000 from the unexpended balance."

By resolution of the Board a special committee of five, consisting of the Chancellor, Senators Cullom and Platt, and Representatives Adams and Dinsmore, was appointed to consider the question of specifically defining the powers of the executive committee, to report at a special meeting called for March 12, 1903.

The special meeting was held on March 12, when the Chancellor reported informally upon the duties heretofore discharged by the executive committee. No definite conclusion had been reached as to the question of defining the powers of that committee, but it was thought desirable that it should hold regular meetings and that the Board of Regents should hold two stated meetings in addition to the annual meeting prescribed by law. It was therefore resolved—

"That, in addition to the prescribed meeting held on the fourth Wednesday in January, regular meetings of the Board shall be held on the Tuesday after the first Monday in December and on the 6th day of March, unless that date falls on Sunday, when the following Monday shall be substituted."

The special committee was continued, with a request to further pursue the examination of the whole subject and to report at the December meeting.

Senator Platt read a clause from the sundry civil act approved March

3, 1903, authorizing the Regents to commence the erection of a new building for the National Museum, to cost not to exceed $3,500,000, and to make contracts for its completion subject to appropriations by Congress. Two hundred and fifty thousand dollars was appropriated to begin the work, the construction to be in charge of Bernard R. Green, Superintendent of Buildings and Grounds, Library of Congress. The resolution adopted by the Board will be found on page 17, under the heading "National Museum."

Mr. Bell introduced resolutions providing for appointments under the Institution, which were referred to the special committee already existing.

Upon motion of Senator Cockrell, the Secretary was authorized to cause to be prepared a compilation of all laws or parts of laws referring to or in any manner affecting the Smithsonian Institution and the bureaus under its charge, including all appropriations by Congress for its purpose or use.

Referring to previous action of the Board concerning the removal of the remains of James Smithson to this country, Mr. Bell offered to bring them to the United States if the Regents would care for them thereafter, and after remarks the suggestion was accepted that Mr. Bell renew his inquiry at the next meeting.

ORGANIZATION OF BOARD OF REGENTS.

As organized at the end of the fiscal year, the Board of Regents consisted of the following members:

The Hon. M. W. Fuller, Chief Justice of the United States, Chancellor; the Hon. W. P. Frye, President pro tempore of the United States Senate; Senator S. M. Cullom; Senator O. H. Platt; Senator Francis M. Cockrell; Representative R. R. Hitt; Representative Robert Adams, jr.; Representative Hugh A. Dinsmore; Dr. James B. Angell; Dr. Andrew D. White; the Hon. J. B. Henderson; Prof. A. Graham Bell; the Hon. Richard Olney, and the Hon. George Gray.

ADMINISTRATION.

The general supervision of the business of the several dependencies placed by Congress under the direction of the Institution has year by year required my increased attention, although as far as practicable the carrying out of details has been left to those in immediate charge of the work of the bureaus.

In view of the great development in the science of ethnology during recent years it seemed desirable that the work of the Bureau of American Ethnology should be reorganized, and in order that I might have full knowledge of the needs of that Bureau a committee was appointed to secure detailed information from those engaged in that branch of the Institution's activities, and to make recommendations based upon the results of their observations. The committee began this work toward the close of the fiscal year.

BUILDINGS.

Certain much-needed repairs to the main roof of the Smithsonian building are in progress, and in this connection it seems important to again call attention to the necessity of a reconstruction of the ceiling and other renovations of the large Anthropological Hall, whose noble dimensions deserve a worthier treatment, and of improving the access to it.

In the paragraphs devoted to the Museum and to the Zoological Park mention is made of building improvements during the year.

FINANCES.

The permanent funds of the Institution are as follows:

Bequest of Smithson, 1846		$515,169.00
Residuary legacy of Smithson, 1867		26,210.63
Deposit from savings of income, 1867		108,620.37
Bequest of James Hamilton, 1875	$1,000.00	
Accumulated interest on Hamilton fund, 1895	1,000.00	
		2,000.00
Bequest of Simeon Habel, 1880		500.00
Deposit from proceeds of sale of bonds, 1881		51,500.00
Gift of Thomas G. Hodgkins, 1891		200,000.00
Portion of residuary legacy of Thomas G. Hodgkins, 1894		8,000.00
Deposit from savings of income, 1903		25,000.00
Total permanent fund		937,000.00

Under the provisions of the act organizing the Institution and the act of Congress approved March 12, 1894, the above fund is deposited in the Treasury of the United States and bears interest at 6 per cent per annum. In addition to the permanent fund, the regents hold certain approved railroad bonds, which form part of the fund established by Mr. Hodgkins for investigations into the properties of atmospheric air.

The unexpended balance at the beginning of the fiscal year, July 1, 1902, as stated in my last report, was $81,120.91. The total receipts by the Institution during the year were $67,835.37. Of this sum, $56,400 was derived from interest and the remaining $11,435.37 was received from miscellaneous sources.

The disbursements during the year amounted to $93,448.61, the details of which are given in the report of the executive committee. This amount includes the sum of $25,000 which, in accordance with a resolution of the Board of Regents adopted at the last annual meeting, was drawn from the current funds and deposited in the Treasury of the United States to the credit of the permanent fund. The balance remaining to the credit of the Secretary on June 30, 1903, for the expenses of the Institution was $55,507.67. A considerable part of

this balance is held against certain contingent obligations which may be expected to mature as a result of various scientific investigations and publications in progress.

The Institution was charged by Congress, during the fiscal year 1903, with the disbursement of the following appropriations:

International Exchanges		$26,000.00
American Ethnology		50,000.00
Astrophysical Observatory		15,000.00
United States National Museum:		
Furniture and fixtures	$22,500.00	
Heating and lighting	18,000.00	
Preservation of collections	180,000.00	
Purchase of specimens	10,000.00	
Postage	500.00	
Books	2,000.00	
Rent of workshops	4,400.00	
Repairs to buildings	15,000.00	
Plans for additional Museum building	5,000.00	
Publishing contributions from Museum herbarium	7,000.00	
Printing	17,000.00	
		281,400.00
National Zoological Park	90,000.00	
National Zoological Park, elephant house	10,000.00	
		100,000.00
Total		472,400.00

Estimates were forwarded as usual to the Secretary of the Treasury for carrying on the Government's interests under the charge of the Institution for the fiscal year ending June 30, 1904. The following table shows the estimates and the sums respectively appropriated:

	Estimates.		Appropriations.	
International Exchanges		$29,800		$26,000
American Ethnology		60,000		40,000
Astrophysical Observatory		15,000		15,000
National Museum:				
Furniture and fixtures	$22,500		$22,500	
Heating and lighting	18,000		18,000	
Preservation of collections	210,000		180,000	
Purchase of specimens	10,000		10,000	
Books	2,000		2,000	
Postage	500		500	
Rent of workshops	4,400		4,400	
Repairs to buildings	15,000		15,000	
Publishing contributions, Museum herbarium	7,000		....	
Printing	17,000		17,000	
		306,400		269,400
New building for National Museum	....			250,000
National Zoological Park	110,000			95,000
Mammal house	25,000			
Aquarium	25,000			
		160,000		
Total		571,200		695,400

RESEARCH.

It was a part of the original plan of the Institution that its Secretary should not give his time wholly to administrative duties, but should directly aid in its scientific investigations.[a]

Research work in various fields of science has been continued by the Institution and its dependencies.

I have made some progress toward the solution of the problem of mechanical flight, and have been carrying on, with the consent of the Regents, some experiments for the War Department, at its expense, and am adding other experiments, partly at the expense of the Institution.

In the Astrophysical Observatory I have continued work believed to be important, and inaugurated some experiments of novel interest, which are referred to later.

Through the Museum and the Bureau of American Ethnology the Institution has been enabled to carry on various biological and ethnological researches, which will be found fully described elsewhere in this report and need not be repeated here.

HODGKINS FUND.

Reports giving the final results of some important investigations which have been prosecuted by the aid of the Hodgkins fund and others, giving the details of the progress of researches still incomplete, have been received. Several of these memoirs have already been issued by the Institution, and others are in course of publication.

The second memoir by Dr. Carl Barus, referred to in my last report as supplementary to the investigation on ionized air, has been published as one of the Smithsonian Contributions to Knowledge, under the title "The Structure of the Nucleus." Questions necessarily left outstanding in the first memoir are answered in the second, the two volumes forming together a valuable contribution to the literature of the subject.

The thermometric researches of Prof. M. W. Travers, of University College, London, have been reported on in a memoir entitled "On the Attainment of Very Low Temperatures," which is now in course of publication. It is the design of Professor Travers to prosecute his investigation still further, and the question of another grant for the purpose has been submitted for consideration.

The research on vacuum spectroscopy, by Dr. Victor Schumann, of Leipzig, has been reported on in detail in a memoir soon to be issued as one of the Contributions to Knowledge. The special apparatus,

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[a] *Resolved*, That the Secretary continue his researches in physical science, and present such facts and principles as may be developed for publication in the Smithsonian contributions. (Adopted at meeting of the Board of Regents January 26, 1847.)

which has been both designed and constructed by Doctor Schumann for conducting this advanced and difficult research, is described in his report. The interest among specialists in this investigation has been so general that the Institution has permitted Doctor Schumann to publish without delay significant discoveries made in the course of his experiments, on the condition of announcing them at the same time to the Institution and mentioning the relation of his work to the Hodgkins fund.

In February, 1903, Prof. E. W. Scripture, of Yale University, whose special researches relative to speech or phonetics have called attention to his work, received a Hodgkins grant for the construction of a "vowel machine," which, when perfected, he hopes will be equivalent to devising a perfect vox humana stop for the organ, which may replace the one now in use. In accordance with the rule of the institution the application for this grant was referred for an opinion to the highest accessible authority before approval.

A grant in form of a subscription for a specified number of copies of the journal Terrestrial Magnetism and Atmospheric Electricity has been again approved, it being apparent that the publication is of service to the specialists and educational establishments that have been placed on the list to receive it through the Institution.

Any general allotment of the income from the Hodgkins fund is precluded by the terms of the bequest, but it may be again repeated that every request for such assistance receives attention, and an application by an investigator who is able to comply with the conditions established in accordance with the will of the donor is sure of serious consideration.

NAPLES TABLE.

The contract for the Smithsonian Table in the Naples Zoological Station, which was extended from June 30, 1902, through December of that year, has been again renewed for one year from January 1, 1902.

The applications for the Smithsonian seat have been so numerous and so urgent that the Institution felt called on to engage another table for a part of the year. This, however, Doctor Dohrn could not arrange for, but with his usual kindness he promised in any event to accommodate all the Smithsonian appointees. He has not only done this, but in several instances has exceeded the requests of the Institution. During the period from March 1 till July 1, 1903, the table had constantly two occupants. It should be added that whenever the dates of applications interfered with each other the approval of the Secretary was accorded, with the understanding that the tenure of the seat should be subject to such modification as might be suggested by the Director of the Station.

Dr. C. W. Prentiss, of Harvard University, whose application for an extension of his occupancy was noted in my last report, remained

at the Station on the invitation of Doctor Dohrn, pending a decision as to the renewal of the Smithsonian lease. His occupancy was afterwards extended until August 1, making a session of five consecutive months. Preliminary mention of his research has been received from Doctor Prentiss, in which he speaks of the exceptional opportunities afforded at Naples for obtaining valuable living material for his researches.

During the summer of 1902 Dr. T. H. Morgan, of Bryn Mawr College, filled another short appointment at the table, and has since transmitted to the Institution copies of two published memoirs detailing the results of his work.

Dr. C. M. Child, of the University of Chicago, occupied the Smithsonian seat from July 1 till December 31, 1902. His report, which indicates briefly the results of his work without extended discussion, is to be published in the first quarterly issue of the Smithsonian Miscellaneous Collections, together with the other papers which have been submitted, in accordance with the request of the Institution, for this purpose by those who have recently occupied the Smithsonian seat.

Dr. C. S. Minot, of Harvard University, who filled an appointment from October 15 till December 15, 1902, reports that his time at Naples was devoted to procuring series of embryos of *Torpedo ocellata*, *Mustelus lævis*, *Petromyzon*, and *Amphioxus*, and also young specimens of *Pristiurus* and *Scyllium*. Doctor Minot also refers to the ample resources of the Station, which enabled him to obtain fine series in carefully selected stages of development. These specimens have been arranged in serial sections and placed in the Harvard embryological collection, where they will be open to all competent investigators and will serve for many years for studies in comparative embryology.

Prof. F. M. MacFarland, of Leland Stanford Junior University, occupied the Table for five months from November 1, 1902. This was Professor MacFarland's second term of occupancy, he having been appointed to the seat for three months in the spring and summer of 1896.

Dr. C. B. Davenport, of the University of Chicago, held the seat for parts of November and December, 1902. In a report promptly submitted at the termination of his occupancy, Doctor Davenport says that during his short period at Naples he made an investigation into the development of the color pattern and specific markings of the shell of *Pecten jacobaeus*, *P. varius*, and *P. pusio*, having also gathered materials for a quantitative variation study of the shells of this species.

Prof. C. W. Hargitt, of Syracuse University, the approval of whose application was necessarily postponed awaiting a decision as to the renewal of the lease, received the appointment for March, April, and May of the current year, during which time he completed a research

on the early development of Eudendrium. A brief summary of the work of Doctor Hargitt has been received and will appear in the first quarterly issue of the Smithsonian Miscellaneous Collections. A more detailed report is to be published later in the Zoologisches Jahrbuch.

Dr. C. H. Bardeen, associate professor of anatomy in Johns Hopkins University, occupied the Smithsonian seat during the months of April, May, and June, 1903, for the purpose of making experimental investigations in embryological development.

In view of the exceptional opportunity for special research afforded at the Naples Station, which is frequently mentioned appreciatively in the reports submitted by the appointees of the Institution, the Secretary is glad to have found it practicable to renew again the lease of the Smithsonian Table, which he hopes on the expiration of the present contract to be in a position to extend for another term of years.

The submission by a Smithsonian appointee of a brief summary of the work done at Naples is an appreciated courtesy, but it may be again stated that should an investigator desire to publish the results of his work on his own responsibility, a copy of his memoir has always been deemed sufficient for the purpose of the Institution, which is chiefly to make suitable reference in the annual report to the often noteworthy work of those occupying the Smithsonian seat.

It may be said that while the summary of the scientific history of an applicant, which it is customary to submit with a request for an appointment, is often unnecessary as a means of acquainting the Institution with the work of an investigator, such a sketch is of service in completing the files of the Institution relative to each appointee, and an abstract of the data thus submitted is transmitted to Doctor Dohrn, with each notice of an approved application, for the files of the zoological station.

Dr. T. H. Morgan, of Bryn Mawr, who has several times filled vacancies caused by the absence of members of the advisory committee, courteously consented again to supply the place of Prof. E. B. Wilson, during his absence in Europe from February till September, 1903. With this exception the personnel of the committee has been unchanged during the year. It gives me pleasure to record again my appreciation of the aid rendered me by the committee in all questions relating to appointments to the Smithsonian table.

EXPLORATIONS.

The Institution has continued to carry on various biological and ethnological explorations through the medium of the National Museum and the Bureau of American Ethnology, and has also cooperated with the Executive Departments in these directions. The details of most of these explorations are given in the paragraphs devoted to the several bureaus.

PUBLICATIONS.

The Institution issued during the year a total of 45,506 volumes or separates of the series of Contributions, Miscellaneous Collections, Reports, and publications not included in the regular series.[a] The document division received for action a total of 8,522 letters and cards of acknowledgment.

In the publications of the Institution the double aim of its founder is represented, in that it should exist for (1) the "increase" and (2) the "diffusion" of knowledge.

The recording of results of original researches, the "increase" of knowledge, is chiefly through the series of Contributions to Knowledge, a quarto work begun in 1848, and in which more than 140 valuable memoirs, collected in 32 volumes, have so far been published. There has been added to this series during the year a memoir of 190 pages by Dr. Carl Barus on the Structure of the Nucleus, a continuation of his experiments with ionized air, which were described in a memoir published during the previous year.

In the present investigation the author answers certain practical questions suggested by his last memoir in relation to phosphorus when used as a source of nuclei; i. e., of extremely small particles tending to precipitate water from moist air when this is suddenly cooled. It is, however, the chief aim of the memoir to throw light on the phenomena connected with the presence of nuclei in air by aid of the coronas or color rings seen in such air when its moisture is condensed and deposited on the nuclei and a distant source of light is looked at through the turbid medium. As these coronas occur in great variety and size they lend themselves to measurement when other means fail. A systematic study is therefore made at the outset of the number of particles corresponding to all well-defined members of the sequence of coronas obtained under known conditions of supersaturated air. The numbers run from less than 100 to upward of 50,000 per cubic centimeter.

The results are then applied in an endeavor to find the velocity of the nucleus by nonelectrical methods, both of a direct and an indirect kind, utilizing the fact that if nuclei leave the medium the coronas obtained under like conditions must change correspondingly. Throughout the latter part of the investigation the nuclei are purposely produced in the simplest manner possible, by shaking solutions in air; but in the course of the investigation the author reaches conclusions which seem to show that the solutional nucleus is of much broader meteorological significance in its bearing on atmospheric condensation and electricity than has heretofore been anticipated. It appears that

[a] Contributions to Knowledge, 1,983; Miscellaneous Collections, 11,667; Reports, 26,237; publications not in regular series, 5,619.

in an unbounded region of the atmosphere saturated with water this nucleus must be a persistent structure. This he finds is strikingly apparent even when the air is saturated with very volatile liquids other than water.

In conclusion, the author points out that the size of the nucleus must vary with the medium in which it is suspended, and that water nuclei in particular will depend for their dimensions on the meteorological status of the atmosphere. Finally, the importance of correlating this variation of nuclear diameter with the electrical activity of the water nucleus is insisted on, with a view to its possible application to atmospheric electricity.

A memoir by Dr. Victor Schumann on the absorption and emission of air and its ingredients for light of wave lengths from 250 $\mu\mu$ to 100 $\mu\mu$ was put in type during the year, but the presswork was not completed.

This memoir, which forms the concluding part of Volume XXIX of the Smithsonian Contributions to Knowledge, gives an account of researches, aided by grants from the Hodgkins fund, on the emission and absorption of the gases of atmospheric air in the ultraviolet spectrum. Within the last fifteen years our knowledge of radiation has been greatly increased, and now embraces wide ranges of the spectrum heretofore unknown. Without assigning any place to the numerous kinds of "rays" whose discovery has been associated in the public mind first with the work of Röntgen and later with that of the Curies, I am speaking here rather of the extensions of the spectrum in wave lengths which are actually measurable and known. Thus beyond the red the spectrum has now been studied in practical continuity to a wave length of nearly 100 microns; and at a great remove beyond this is another known region embracing the so-called Hertzian or electric waves now employed in wireless telegraphy. Beyond the violet progress has been, relatively speaking, less rapid, unless, indeed, it shall prove that the Röntgen and other radiations fall in this region. But a great step in advance has been made by the unwearied investigations of the author of the present work, Doctor Schumann.

The difficulties hindering research in the ultraviolet are great and consist chiefly in the opacity of the usual optical media to the short wave-length rays. Quartz, for a long time considered best in this part of the spectrum, is found to be too opaque, and has been largely superseded in Doctor Schumann's investigations by fluorspar for prisms and plates. Air, even in layers of a few millimeters' thickness, is almost wholly opaque, and other gases absorb strongly. It has, therefore, been necessary to employ a spectroscope from which the air is exhausted to the highest practicable degree; and this and other necessary apparatus Doctor Schumann has designed and constructed with his own hands, though aided by grants from the Hodgkins fund of the Smithsonian Institution.

The memoir contains an account of the special apparatus and method of using it, and continues with a description of the emission and absorption spectra of oxygen, nitrogen, hydrogen, carbon monoxide and dioxide and aqueous vapor for wave lengths, reaching in the case of hydrogen to about 0.10 micron. Illustrations of the apparatus and spectra accompany the text, and it is thought the whole will be a valuable contribution to knowledge, though but preliminary to the researches Doctor Schumann alone is continuing in this spectral region.

The Institution has accepted, for publication in the Contributions to Knowledge, a memoir by Dr. Frederick W. True, entitled "The whalebone whales of the western North Atlantic, compared with those occurring in European waters, with some observations on the species of the North Pacific." This memoir will make a volume of about 200 pages of text, accompanied by about 50 full-page plates illustrating the anatomy and habits of the various species described.

For many years I have had a hope of preparing for publication a work consisting essentially of photographic views of the moon so complete and, it was expected (with the advance of photography), so minute, that the features of our satellite might be studied by the geologist and the selenographer nearly as well as by the astronomer at the telescope. This hope has been disappointed, for photography, which has made such eminent advances in the reproduction of nebulæ and other celestial features, has stood comparatively still in lunar work. We indeed have far better views than were obtained by Rutherford, but the very best even of the admirable ones recently procured by Professor Ritchey at the Yerkes Observatory have proved so far behind what the eye can directly discern with the telescope that the expectation that such a work could be advantageously published has been, after a great deal of labor and preparation for many years, most reluctantly abandoned. During the past year, however, a memoir has been submitted to the Institution by Prof. N. S. Shaler, of Cambridge, entitled "A Comparison of the Features of the Earth and the Moon." It will be published with some of the best illustrations gathered for the former purpose, and about 25 of these illustrations of the moon's surface, including many of the photographs taken by Professor Ritchey, will form a prominent feature. The work will probably appear in the early part of the ensuing year.

In 1864 the Institution published in the series of Contributions to Knowledge a memoir by Prof. Henry Draper on the Construction of a Silvered Glass Telescope. The book has long been out of print, and as there seemed to be a present demand for a new edition arrangements have been made for its reissue, accompanied by an article by a competent hand bringing the subject to date.

To the series of Miscellaneous Collections two short papers were

added during the year, and several papers were accepted and progress made toward their publication. Among the accepted papers may be mentioned an Index to the Literature of Thorium, 1817–1902, by Dr. Cavalier H. Joüet; a Second Supplement to Select Bibliography of Chemistry, by Dr. H. C. Bolton, bringing the subject down to close of the year 1902; Researches on the Attainment of Very Low Temperatures, by Prof. Morris W. Travers, of University College, London, and a paper by Dr. Amadeus W. Grabau, on the phylogeny or tribal history of Fusus and its allies, being a very complete description of the various fossil and recent genera and species classed by conchologists under the name Fusus.

Among the proposed publications may be mentioned an elaborate work by the late Dr. G. Brown Goode on "What has been done in America for Science." Doctor Goode left the manuscript nearly completed, and arrangements have been made to bring it to date and to put it in condition for printing.

The revised edition of the Smithsonian Physical Tables, issued in 1897, having become exhausted, and the demand continuing, a second edition was printed in January, 1903.

Arrangements have been made for a quarterly issue of the Smithsonian Miscellaneous Collections in order to afford a medium for the prompt publication of brief accounts of the results of researches by the Institution and its bureaus, especially those of a preliminary nature, together with such notices concerning the Institution and its activities as may be of general public interest. Each issue will consist of about 140 pages of text and will be amply illustrated. The quarterly issue will supplement, not replace, the regular series of the Miscellaneous Collections.

Mention has heretofore been made of the character of papers published in the General Appendix of the Regents' Report to Congress. This report, to which I have given much personal care, is the only Smithsonian publication issued in large numbers, and yet the popular demand for it is far in excess of the edition of 12,000 copies authorized by law. The volume for 1901 was received from the Public Printer early in the autumn of 1902 and in a very few weeks every available copy was distributed. It is desirable that a larger edition should be authorized.

The manuscript for the 1902 report was sent to the Public Printer in May, 1903, and most of it was in type before June 30.

Besides the above publications of the Institution itself a large number of works on anthropological, biological, and geological subjects, issued by the National Museum and the Bureau of American Ethnology, are referred to in detail in appendices to this report. There was also sent to press a report by the Astrophysical Observatory on the solar eclipse expedition of 1900. The Secretary of the Institution received

and submitted to Congress, in accordance with their acts of incorporation, the annual reports of the American Historical Association and of the National Society of the Daughters of the American Revolution.

LIBRARY.

The accessions to the Smithsonian deposit in the Library of Congress during the year were 1,848 volumes, 21,282 parts of volumes, 3,804 pamphlets, and 379 charts, or a total of 27,313, being an increase of 675 over the previous year, and extending the accession numbers of the Smithsonian deposit to 452,465. The libraries of the Secretary, Office and of the Astrophysical Observatory show an increase of 409 volumes, pamphlets, and charts, and 1,625 parts of volumes, making the total Smithsonian library accessions of the year 29,347. The serial publications entered on the card catalogue number 24,630.

Gen. John Watts De Peyster has added to his large collection of books and pamphlets relating to Napoleon Bonaparte, and has also presented a collection of works on gypsies, a collection of dictionaries and encyclopedias, many of which are very rare, besides several portraits, pictures, and paintings.

The National Museum library now contains 19,161 bound volumes and 32,063 unbound papers. The accessions during the year were 3,161 books, 3,260 pamphlets, and 303 parts of volumes, which include two important gifts—the E. A. Schwarz collection of books on American Coleoptera and the W. H. Dall collection of books on recent and fossil mollusks. The librarian refers to these gifts in some detail in his report in the Appendix.

The Institution has continued to aid in the maintenance of the International Catalogue of Scientific Literature, and a total of 14,480 references were furnished to the central bureau during the year. Five volumes of the Catalogue were received and distributed.

CORRESPONDENCE.

The correspondence of the Secretary's office embraces not only communications referring to the work of the Institution proper, but also to the National Museum, the International Exchanges, the Bureau of American Ethnology, the National Zoological Park, and the Astrophysical Observatory.

Subjects of inquiry by correspondents are perhaps more varied and embrace a wider range of topics than obtains in other departments of the Government, yet all are promptly answered.

MISCELLANEOUS.

Hamilton fund.—I have given consideration to the difficult subject of the useful disposition of the small Hamilton fund, the income of

which it is hoped to apply to a biennial lecture, but no arrangements have yet been perfected for its delivery.

Gifts.—Among the gifts received by the Institution during the year may be mentioned a large oil painting, "The March of Time," presented by the artist, Mr. Henry Sandham, representing many of the principal generals of the civil war.

Louisiana Purchase Exposition.—Congress having made an appropriation for a Government building and exhibit at the exposition to be held in St. Louis in 1904, the Secretary has appointed Doctor True to represent the Institution and its bureaus in the preparation and installation of its exhibits.

Congress of Americanists.—Mr. F. W. Hodge was delegated to represent the Institution at the thirteenth session of the International Congress of Americanists, held at New York, October 20–25, 1902. The session was successful in every respect; many foreign governments and institutions of learning in Europe and throughout the American Continent were represented, and the communications presented covered the entire field of aboriginal American history, anthropology, ethnology, archæology, and linguistics.

Congress of Orientalists.—Prof. Paul Haupt, LL. D., honorary curator of the division of historic archæology in the United States National Museum, attended the Thirteenth International Congress of Orientalists as delegate of the Smithsonian Institution. This congress, which was held at Hamburg, Germany, from September 4 to September 10, 1902, was organized in eight sections: I, Indo-European Linguistics; II^{a}, India; II^{b}, Iran; III, Indo-China and Oceania; IV, Central Asia and the Far East; V, Semitic; VI, Islam; VII^{a}, Egyptian; VII^{a}, African; VIII, Relations between Orient and Occident (including Byzantine studies). At first it was proposed to have a special colonial section, but this idea was afterwards abandoned owing to the fact that a special colonial congress was held at Berlin in October, 1902. The Hamburg congress, which was attended by more than 600 members from all parts of the globe, resolved to depart from the practice of printing the transactions in full and to publish only a volume of proceedings, including abstracts of all the papers presented and the subsequest discussions, to be issued within half a year after adjournment. This volume has as yet not appeared. The next congress will be held at Algiers in April, 1905.

NATIONAL MUSEUM.

An important epoch in the history of the National Museum has occurred during the past year, when, by act of March 3, 1903, Congress provided for the erection of an additional building, to cost not to exceed $3,500,000.

The present building was completed in 1881 and was erected pri-

marily to accommodate the mass of objects received by the Government from the International Exhibition at Philadelphia in 1876, these objects having been in storage for several years. The present building was cheaply erected and was not expected to meet the requirements of a great national museum, and Secretary Baird soon found it necessary to present to Congress the question of constructing a more adequate one; and already in 1888, in my early incumbency, this was represented to the Regents. Although Congress at various times during the past twenty years has had the matter under consideration, definite action was not taken by both Senate and House. During the first session of the last Congress, however, a small appropriation was made for preparation of plans for a new building, as I stated in my last report. Preliminary plans were submitted to Congress at its last session and authority has been granted to the Regents of the Institution to proceed in the construction of an additional building, to contain about 10 acres of floor space, or treble that we have at present, which will be worthy to accommodate the great collections of the nation.

The law reads as follows:

"Building for National Museum: To enable the Regents of the Smithsonian Institution to commence the erection of a suitable fireproof building with granite fronts, for the use of the National Museum, to be erected on the north side of the Mall, between Ninth and Twelfth streets northwest, substantially in accordance with Plan A, prepared and submitted to Congress by the Secretary of the Smithsonian Institution under the provisions of the act approved June twenty-eighth, nineteen hundred and two, two hundred and fifty thousand dollars. Said building complete, including heating and ventilating apparatus and elevators, shall cost not to exceed three million five hundred thousand dollars, and a contract or contracts for its completion is hereby authorized to be entered into, subject to appropriations to be made by Congress. The construction shall be in charge of Bernard R. Green, Superintendent of Buildings and Grounds, Library of Congress, who shall make the contracts herein authorized and disburse all appropriations made for the work, and shall receive as full compensation for his services hereunder the sum of two thousand dollars annually in addition to his present salary, to be paid out of said appropriations."

The Regents, at their meeting of March 12, adopted the following resolution:

"*Resolved*, That the Secretary, with the advice and consent of the Chancellor and the chairman of the executive committee, be authorized to represent the Board of Regents, so far as may be necessary, in consultation with Bernard R. Green, to whom the construction and contracts for the new Museum building are committed by Congress in the act making an appropriation for that purpose."

The final plans for the new structure were commenced toward the close of the fiscal year, and the construction will be pushed as rapidly as is consistent with the magnitude of the work. It has been decided to locate the building on the northern side of the Smithsonian Park.

facing the present Smithsonian and Museum buildings, though at a distance of several hundred feet. It will be a fireproof building with granite front and will have about 500 feet frontage and be about 330 feet deep, with four stories, including the basement. The main and second floors will be used for exhibition halls, while the basement and third floors will serve for laboratory and storage purposes.

I have great pleasure in recording this final result of the recommendations of the Regents and their Secretary and of the good will of Congress.

The year shows marked progress in nearly every branch of the Museum. Two hundred and thirty-six thousand specimens were received, making the present total over 5,650,000, and there were distributed to educational establishments about 33,000 objects. Letters requesting information show an increase of about 25 per cent in number, and nearly 900 lots of specimens were received for identification. The distribution of publications also shows an increase over previous years, and to the library some valuable collections of books on special zoological subjects have been added.

Among the anthropological accessions during the year I may mention some interesting specimens illustrating the native arts and industries of Sumatra and the Straits Settlements, collected by Dr. W. L. Abbott; a large ethnological collection from the Philippines, furnishing information regarding the life and customs of the natives of those islands; a number of bronzed wooden images representative of Buddhist religious art, a series of models of United States war vessels, and of land and naval ordnance; and some relics of General and Mrs. Grant of much intrinsic and historic interest, presented by their children.

The biological and geological departments of the Museum also received valuable additions, which are enumerated in the report of the Assistant Secretary, where will also be found details in regard to explorations and researches conducted under direction of the Museum.

BUREAU OF AMERICAN ETHNOLOGY.

Researches among the American Indians have been continued by the Bureau as outlined in the plan of operations submitted June 30, 1902, and approved by me May 23, 1903.

The earlier part of the (fiscal) year was marked by the death of Maj. John W. Powell, and in October Mr. W. H. Holmes was appointed his successor.

Major Powell was born March 24, 1834, and died September 23, 1902. He organized the Bureau of Ethnology and under the general direction of the Institution carried on its researches until his death.

The story of his well-filled life has been told by others; he was too near and too dear a friend for me, perhaps, to speak of it with a wholly impartial judgment, but I am glad to believe that I, too, had acquired his friendship and that this mutual feeling colored all our relations.

Major Powell, who had taken his part in the great events of our civil war (where he served as captain of artillery under Grant at Vicksburg) and who had lost an arm in his country's service, was first known to me, as to many others, by one of the most remarkable feats of exploration left for anyone to accomplish.

The old Spanish explorer, Coronado, who in 1540 penetrated to what is now known as the Grand Canyon of the Colorado, came back with the story of a crack in the earth at the bottom of which the great tower of the cathedral of Seville would seem no bigger than a man. This was set down as a traveler's tale.

In this unexplored region the Colorado River, however, was found to flow for nearly 1,000 miles through scenery unequaled on this globe, for during a great part of its course it is bounded by walls over a mile in altitude, at the bottom of which the unknown stream descends with frequent falls through a channel from which there is no escape except by climbing the nearly impassable precipices which shut it in. The river is the only road, and its entire course abounds in hourly perils. This was the scene of Major Powell's exploration in 1867, which, though conducted for purely scientific purposes, yet, considering all that it involved, may be called one of heroic adventure, while the skill which overcame every difficulty was not less conspicuous than the courage of the leader, who, maimed as he was, fought with constant physical perils, but came through safely together with those who had trusted their lives to his guidance. None of his subsequent distinguished scientific life will ever efface the memory of this splendid feat. It is one which surpasses in all its elements of interest and danger, perhaps, the work of any such explorer of modern times.

I leave to more competent hands the description of the great and notable work in geology and ethnology which occupied Major Powell's later life, and only add a few words on some qualities of the man best known to an intimate friend.

I have been with Major Powell in the life of the city and in the life of the wilderness, and wherever I have been with him I think I have been more impressed with the simplicity and self-comprised nature of his character than even with the complexity of his knowledge and achievements. Besides his splendid capacity for leadership in battle and adventure, besides his varied knowledge as a scientific man, the mystery of this world, which pure science so little recognizes, was always present to Major Powell's mind; the lapse of ages,

the wonderful birth of species, the path that threaded past time on and up to man—all these things were present to his thought and colored his work, were always associated with what he did as a man of science, and constituted his innermost point of view.

He was a generous man, kind to others and helpful; a brave and always a self-contained man who found in himself counsel sufficient for his need. He was a stoic who suffered long years of pain in silence, and who, at the end, met the approach of death as though it were a familiar incident of life. We shall not often look upon his like.

In the past year's work of the Bureau scientific researches among Indian tribes in the field, in documentary investigations, and in laboratory and general office routine have been pursued with the usual effectiveness. Systematic field work has been successfully prosecuted in many States and Territories and in San Domingo and Porto Rico. Six members of the staff have spent periods of greater or less extent in the field and have secured materials for embodiment in reports. These researches have furnished data bearing more or less fully upon numerous branches of the science of man, including tribal classification and history, languages, religions, social systems, arts and industries, æsthetics, and welfare.

A principal feature of the year's work has been the taking up, with renewed vigor, of the preparation of the dictionary of Indian tribes, which had been on hand for a number of years. The plan contemplates the publication of two octavo volumes, which shall embody in compact form the great body of information gathered during the past years regarding the American race, its linguistic families, tribes, villages, individuals, and history, and make more evident the great utilities of the Bureau's work. The first volume was practically ready for the press at the close of the year, but to my regret the resolution providing for the issue of the work in octavo form did not reach a vote during the session of Congress, and the manuscript was not transmitted to the printer.

The reading of proofs of reports in press, the preparation of illustrations for forthcoming volumes, and the photographing of visiting Indians have gone on as usual.

INTERNATIONAL EXCHANGES.

The International Exchange Service of the Institution is the medium for exchange of publications between the principal governments and scientific institutions and libraries of the world. Every year shows an increase over the work accomplished during the previous year. During the past year the total number of packages handled showed an

increase of 19 per cent over the year 1901–2, and the weight an increase of 41 per cent. Seventy-five per cent of the weight represents packages sent abroad and 25 per cent the weight of packages received from foreign countries.

The total number of correspondents or beneficiaries of the facilities of the exchange service at home and abroad aggregates 44,012, of which 13,121 are foreign institutions, 21,332 foreign individuals, 3,319 domestic institutions, and 6,240 domestic individuals.

In 1901 Congress increased from 50 to 62 the number of sets of official documents of this country to be exchanged with foreign countries, and provided for a further increase to 100 sets when deemed expedient in the judgment of the Librarian of Congress. Thus far, however, the institution has been called on to transmit through its exchange service only 12 parts of sets to foreign exchanges, thus leaving 12 full sets actually provided for and 26 additional sets, or such parts thereof as may be deemed necessary, still available for exchange with other countries.

NATIONAL ZOOLOGICAL PARK.

The collection of animals housed and cared for in the National Zoological Park continues to increase in interest and value, and in order to adequately provide for it new buildings for special groups of animals need to be erected. During the past year an elephant house has been built, which, owing to the limited appropriation, can only be spoken of as a considerable improvement over the temporary quarters previously occupied.

It is expected that the funds provided under the general appropriation for the present year will permit the commencement of the construction of a house for small mammals, which is the next most important need.

As the number of buildings in the park increases it becomes necessary to consider a method of heating them in an effective and economical manner. At present each separate building has its own heating apparatus, each requiring the employment of a special set of men for its care and management. It would conduce to economy both in fuel and in service if all the buildings in the park lying within a reasonable radius could be heated from a central heating plant, which could be managed by a single set of men.

Considerable additions to the collection have been made during the year through the public spirit of Dr. F. W. Goding, United States consul at Newcastle, New South Wales, who has sent more than 140 specimens of the unusually interesting fauna of that region. This shows in a remarkable manner what can be done by our officers abroad

who are fully awake to the needs of our national collection and are willing to devote some of their time to its enrichment.

I have repeatedly called attention to the wasteful destruction of Alaskan fauna, and am gratified to say that the last Congress passed an act for its protection, so that it may be reasonably expected that the wholesale slaughter of these interesting animals may be checked. A clause of the act permits the Smithsonian Institution to procure specimens for its use.

The Zoological Park was declared by Congress to be for the advancement of science and the instruction and recreation of the people. It has hitherto more largely fulfilled the second object, but in pursuance of the special scientific activities of the park I hope that there may be established at an early date a pathological laboratory, where much may be learned of the diseases of animals and their relations to those that affect the human family. Such a useful laboratory can be erected at a very moderate cost.

The growth of the city in the vicinity of the National Zoological Park has finally caused a definitive establishment of streets. These do not in all cases conform to the boundaries of the park, which therefore abuts at several places upon the back yards of neighboring residences. This will undoubtedly cause unsightly borders unless some means is taken to prevent it. I have given a full discussion of this subject in my report for the years ending June 30, 1895, and June 30, 1896. The evil has increased rather than diminished, and I would recommend that action be taken by Congress to remedy this condition by purchasing sufficient land to extend the park to the nearest neighboring street throughout its entire boundary.

THE ASTROPHYSICAL OBSERVATORY.

Bolographic studies of the spectrum of the sun and the provision of a large horizontal telescope to be used for studies of special portions of the solar radiation have been the distinguishing features of the work of the Astrophysical Observatory during the past year. Results of uncommon interest have been reached in the bolographic work of the past twelve months, and especially in the studies of the absorption of the solar rays by our atmosphere, as appears in the detailed report of the aid acting in charge, which may be found in the Appendix.

Briefly this has shown that the earth's atmosphere, so far as it can be observed here, has been more opaque than usual within the present calendar year, so much so as to reduce the direct radiation of the sun at the earth's surface by about 10 per cent, on the average, throughout the whole visible and infra-red spectrum, and by more than double this amount in the blue and violet portions of the spectrum. This

alteration of the transparency of the air has not, however, been confined to the region of Washington.

Another interesting observation is that determinations of the rate of solar radiation outside the earth's atmosphere might appear to indicate that there has been a decrease of the solar radiation itself since March 26, 1903; but I refer to this with hesitation, as I have elsewhere observed that it is scarcely possible to be certain of the accuracy of results of this sort when based on observations near sea level. The value of a solar observatory at a high altitude, to which I referred last year, can hardly be overestimated.

A new determination of the temperature of the sun, based on the distribution of the solar radiation in the spectrum, has yielded a result of 5,920° of the centigrade scale above absolute zero.

For the purpose of the special study of the nature of sun spots, the absorption of the solar gaseous envelope, and for other observations requiring a large solar image an equipment including a horizontal reflecting telescope of 140-foot focus and 20-inch aperture and a coelostat of improved construction to furnish at all times a 20-inch horizontal northerly directed solar beam has been provided. The form of coelostat employed seems so well suited to solar work that this large instrument will be exhibited by the Observatory at the Louisiana Purchase Exposition in 1904. Provision has been made in connection with the long-focus telescope to churn the air traversed by the beam from the coelostat to the focal image after the manner described in my last year's report. It is hoped that this installation will have yielded results of interest before another year.

On the whole the work of the Astrophysical Observatory during the past year has been quite as productive of results of interest as during any former year of its existence, especially in showing a notable variation of atmospheric transparency which is likely to have affected climate and the growth of vegetation over a considerable part of the earth's surface, and in the studies of atmospheric absorption and those relating to the solar constant, to which I have referred, there seems renewed promise of progress toward the goal "foretelling by such means those remoter changes of weather which affect harvests," which is one of the great aims had in view in the foundation of the Observatory.

Respectfully submitted.

S. P. Langley,

Secretary of the Smithsonian Institution.

APPENDIX TO THE SECRETARY'S REPORT.

APPENDIX I.

REPORT ON THE UNITED STATES NATIONAL MUSEUM.

Sir: I have the honor to submit the following report on the condition and operations of the National Museum during the fiscal year ending June 30, 1903.

The most noteworthy occurrence of the year, and, in fact, for many years past, was the action of Congress in providing for an additional building for the National Museum, a building that will not only treble the existing amount of space, but also present an imposing and dignified appearance, and be entirely worthy to house the great collections of the nation. The public will be greatly benefited by this measure, and the opportunity will be given to arrange in classified order the great mass of valuable material which, for over two decades, has been accumulating in insecure and inconvenient storage quarters.

Marked progress has been made in nearly every branch of the Museum. The number of specimens received was 236,000, increasing the total now in the possession of the Museum to over 5,650,000. The number sent out in exchange and as gifts to educational establishments was above 33,000. The demands for information by letter were increased at least 25 per cent, and nearly 900 lots of specimens were received for identification. The amount of fieldwork carried on by members of the Museum staff, however, was greatly diminished through lack of means.

There was an increased number and a more extensive distribution of publications, and the library received as gifts two valuable collections of books and pamphlets on special zoological subjects. Preparations for the Louisiana Purchase Exhibition to be held at St. Louis in 1904 were well under way before the year ended, and the fact is now evident that the Museum will have in that connection one of the largest and most interesting exhibits it has ever assembled for such a purpose.

Buildings.—The work upon the final plans for the additional building was commenced near the close of the year, but several months must elapse before the working drawings are sufficiently advanced to begin making contracts. The new structure will stand upon the north side of the Mall between Ninth and Twelfth streets, with its center at Tenth street. Its location is, therefore, directly in front of the present buildings, but at a sufficient distance from them to prevent any clashing between the different styles of architecture. The building will be classic in character and constructed of granite. Its frontage will be about 500 feet, and its depth about 330 feet. It will have four stories, including the basement, the main and second stories to be devoted to the public collections, the others to the storage of the reserve specimens and the various objects of the activities of the Museum. The entire floor area will amount to nearly 10 acres. It is expected that about four years will be required for the completion of the structure.

The repairs about the present Museum building were extensive, owing in large part to the poor condition of the roof, which seems to develop new leaks during

every heavy rain. The rotunda and four main halls have been entirely repainted, and this work was being extended to the four courts at the close of the year. This extensive renovation will place the exhibition halls in a more presentable condition than at any previous time.

Many new cases, both for exhibition purposes and for storage, have been constructed, and much has been accomplished in the rebuilding and repair of old furniture and fixtures.

Organization and staff.—One new division (Physical Anthropology) has been added to the Department of Anthropology, and one new section (Lower Algæ) to the Department of Biology. The scientific organization of the Museum, therefore, now comprises 9 divisions and 4 sections in the Department of Anthropology; 9 divisions and 13 sections in the Department of Biology; and 3 divisions and 3 sections in the Department of Geology. The scientific staff includes 3 head curators, 17 curators, 13 assistant curators, 15 custodians, 12 aids, 4 associates, and 2 collaborators, making a total of 66 persons, of whom only about one-half are paid employees of the Museum, the remainder serving in a volunteer or honorary capacity.

Mr. W. H. Holmes, head curator of the Department of Anthropology, having been appointed Chief of the Bureau of American Ethnology, Prof. Otis T. Mason has been designated to assume his museum duties as acting head curator.

Dr. A. Hrdlicka took charge of the newly organized Division of Physical Anthropology on May 1, as assistant curator, and Dr. G. T. Moore, of the Department of Agriculture, became custodian of the new Section of the Lower Algæ on May 25. The designation of Mr. W. T. Swingle has been changed to that of custodian of the Section of Higher Algæ.

On December 31 Mr. Charles T. Simpson resigned his position as principal aid in the Division of Mollusks, being succeeded by Mr. Paul Bartsch, whose place was in turn taken by Mr. W. B. Marshall, appointed aid on April 1. Mr. R. G. Paine was made an aid in the Division of Reptiles and Batrachians on April 6.

Additions to the collections.—The number of accessions received during the year was 1,643, about 230 more than in 1902, comprising in all about 236,000 specimens. This increases the total number of specimens in the national collections to above 5,650,000. Only the more important additions can be mentioned here.

One of the most valuable acquisitions by the Department of Anthropology consisted of material recently collected by Dr. W. L. Abbott in Sumatra and the Straits Settlements, and illustrating the native arts and industries of a region but poorly represented in American museums. The many objects, numbering over 1,500, secured in the Philippine Islands by the late Col. F. F. Hilder, of the Bureau of American Ethnology, for the Government exhibit at the Pan-American Exposition, have been turned over to the Museum by the Government Board. This collection is of especial interest in that it furnishes much authoritative information regarding the life and customs of the natives of the largest of our new possessions. Dr. Frank Russell, formerly of the Bureau of American Ethnology, secured important material from the Pima Indians of southern Arizona, which, together with many ethnological objects from other sources, have been transferred by the Bureau to the custody of the Museum. Several collections made by Lieut. G. T. Emmons, of the United States Navy, illustrating the arts of the Chilcat and other Alaskan tribes, have also been acquired.

An extremely noteworthy collection deposited in the Museum by Mr. S. S. Howland, of Washington, D. C., consists of objects representing Buddhist religious art, such as bronze and wooden images of Buddha and Buddhist saints, shrines, temple lamps, and sacred writings on palm leaves, and also of several Oriental manuscripts in Hebrew, Arabic, and other languages. Twenty-eight Jewish ceremonial objects from North Africa were obtained from Mr. Ephraim Deinard, of Kearney, N. J., one of the most interesting pieces being an ark of carved wood, containing a parchment

scroll of the Pentateuch. The Egyptian exploration fund has presented some valuable Græco-Egyptian papyri.

Among the accessions to the Division of Prehistoric Archeology were a collection of implements and other objects obtained by Mr. W. H. Holmes from near Kimmswick, Mo., with the assistance of Mr. Gerard Fowke, who also transmitted a number of hammer-stones, flint nodules, and other objects from ancient quarries near Carter, Ky., and a series of implements and specimens of ore, which had been mined for use as paint, from aboriginal hematite mines at Leslie, Mo., collected by Mr. Holmes. About 300 specimens of stone implements, gathered by the late Mr. Frank Hamilton Cushing, including spearheads, arrowpoints, harpoons, and tools of various kinds, and a very important collection made by Dr. J. Walter Fewkes in Porto Rico and Santo Domingo were received from the Bureau of American Ethnology. The material from Santo Domingo comprises many types new to the Museum, while that from Porto Rico contains several stone rings or collars, sculptured pillow stones, the remains of human skeletons, and various other objects.

A series of models of United States war vessels, including gunboats, monitors, protected cruisers, and rams, deposited in the Museum by the Navy Department, form a very attractive exhibit, being of especial interest to the public. The War Department has also deposited a large number of models of heavy seacoast cannon, mountain howitzers, and other types of ordnance formerly used by the Army, and a series of small arms.

Many relics of General and Mrs. U. S. Grant, of great intrinsic as well as historic value, have been presented to the Museum by their children, through Brig. Gen. Frederick D. Grant, U. S. Army. They include clothing worn by General Grant during the civil war, commissions to different ranks in the Army, a cabinet presented to Mrs. Grant by the Empress of Japan, said to be 1,000 years old and valued at $20,000, several Japanese vases presented by the Emperor of Japan, and numerous other objects. Eight hundred and thirty-seven gold, silver, and copper coins were donated to the Museum by Mr. E. M. Chapman, of New York City.

Casts of the Neanderthal and Prague ancient crania were purchased for the newly established division of Physical Anthropology, which has also secured five valuable head-hunter's skulls from New Guinea, and a large series of crania and parts of human skeletons from the Army Medical Museum, the United States Fish Commission, and other sources.

The zoological specimens contributed by Dr. W. L. Abbott consisted of a large number of deer, squirrels, porcupines, and a new ape, collected in Sumatra and on the adjacent islands, and on the Riou Peninsula south of Singápore. Many of the species are new to science. The donations made by Doctor Abbott as the result of his recent extensive explorations in the East Indies now comprise about 2,500 mammals and nearly 4,000 birds, besides several thousand specimens in other branches of natural history.

Large collections of bird skins, fishes, corals, mollusks, crustaceans, and other marine invertebrates, obtained during the expedition of the United States Fish Commission steamer *Albatross* to the Hawaiian Islands and to Samoa, have been transmitted to the Museum and will be referred to more in detail in the next report. They include interesting series of the birds of the Laysan Islands.

Dr. E. A. Mearns, U. S. Army, presented a quantity of mammals from the Yellowstone National Park and from Fort Snelling, Minn., and the Hon. B. S. Rairden, United States consul at Batavia, two undescribed species of *Tragulus* from Java. A valuable skeleton of the porpoise, *Pseudorca crassidens*, from the Hawaiian Islands, the first reported from that region, was contributed by Prof. C. H. Gilbert, of the Leland Stanford Junior University.

Several rare birds of paradise and other valuable specimens, including a pair of flightless cormorants, from the Galapagos Islands, were received from Mr. A. Boucard,

Isle of Wight, England, and a Javan jungle fowl, a black-winged peacock, and other birds from Mr. Homer Davenport, Morris Plains, N. J. The Bishop Museum, of Honolulu, presented about 40 bird skins, including several species not previously represented in the Museum collection, and about 300 interesting specimens from Chiriqui, Costa Rica, including a number of cotypes. Fifty-two bird skins from Honduras were obtained from Mr. Outram Bangs, of Boston, partly as a gift and partly in exchange. The most important accession to the öological collection was a fossil egg of *Aepyornis maximus* from Madagascar. Valuable birds' eggs from Australia, South America, and other countries were also received from different sources.

Reptiles from southern Florida were contributed by Mr. E. J. Brown, of Lemon City, and a fine series of salamanders was presented by Messrs. Brimley and Sherman, of Raleigh, N. C. From Prof. P. Biolley, of the National Museum of San Jose, Costa Rica, there were obtained several very interesting specimens, including a new gecko, described by Doctor Stejneger as *Sphærodactylus pacificus.* Eighteen snakes from the Island of Cyprus were purchased from Giacomo Cecconi, of Florence, Italy.

The accessions to the collection of fishes were numerous and important. Dr. O. P. Jenkins, of Leland Stanford Junior University, donated 42 types of Hawaiian fishes, constituting a second installment of a series of types the first of which were transmitted in 1901. A valuable collection of types and cotypes of Japanese fishes was received from Dr. David S. Jordan, president of the same university. A large salmon, weighing about 50 pounds, taken at Cascapedia, Canada, was presented by Dr. S. Weir Mitchell, of Philadelphia. A deep-sea pelican fish, captured at a depth of between 2,000 and 3,000 fathoms, during the survey for the Pacific cable, was transmitted by the officers of the U. S. S. *Nero*, and a large conger eel was received from Mr. Louis Mowbray, of Bermuda, through the New York Aquarium.

Besides the mollusks obtained by the Fish Commission expedition to the Hawaiian Islands a number of well-preserved land shells from the same region were donated by Mr. W. H. Henshaw, of Hilo, Hawaii. Interesting collections of shells were also received from Dr. Henry Loomis, Yokohama, Japan; Mr. F. A. Woodworth, San Francisco, Cal.; Mrs. T. S. Oldroyd, Burnett, Cal., and the Imperial Academy of Sciences, St. Petersburg. A specimen of the rare *Voluta mamilla* Sby., from Tasmania, and other valuable Australian shells, were also added to the mollusk collection.

Among the most important additions to the entomological division were a collection of over 19,000 specimens of gall wasps, parasites, etc., from Canada, transmitted by the Department of Agriculture; a series of Costa Rican insects of different orders purchased from Mr. P. Schild, of New York City; 2,000 specimens of Chilean insects from Mr. E. C. Reed, Concepcion, Chile; 277 specimens of African Lepidoptera received in exchange from Dr. Yngve Sjostedt, Stockholm, Sweden; a collection of mites, including types and cotypes, from Prof. Robert Wolcott, of the University of Nebraska; specimens of many orders and comprising types and cotypes, from Prof. T. D. A. Cockerell, East Las Vegas, N. Mex.; about 700 specimens of European Coleoptera from Dr. W. H. Valway, Cleveland, Ohio, and a valuable series of Venezuelan *Cicindellidæ* and *Scarabæidæ* from Mr. E. A. Klages, of Crafton, Pa. A collection of African butterflies, including examples of several species described by Doctor Aurivillius, was received in exchange from the Royal Natural History Museum, Stockholm. An important exchange was made with the American Entomological Society, whereby the Museum received 100 species of Mexican and Central American Hymenoptera, including many cotypes. Thirty-four cotypes of Coleoptera were presented by Prof. H. C. Fall, of Pasadena, Cal.

The Division of Marine Invertebrates obtained through exchange with the Museum of Natural History, Paris, France, about 50 species of fresh-water crustaceans. A series of Japanese crustaceans, including many interesting specimens collected by Dr. David S. Jordan and Mr. J. O. Snyder, was presented by the Leland Stanford Junior University. A number of crustaceans from the Maldive Islands, collected by Mr.

Alexander Agassiz in 1901 and 1902, was received from the Museum of Comparative Zoology, Cambridge, Mass., and similar material from Costa Rica and Cocos Island was acquired through exchange with the National Museum of Costa Rica. Among other accessions of special interest may be mentioned four lots of isopod crustaceans, including types obtained by the Harriman expedition, received from Prof. Trevor Kincaid, Seattle, Wash.; 23 specimens of echinoderms and crustaceans from Great Britain and from various localites in the East, contributed by Mr. H. M. Parritt, of London, England; a quantity of foraminifera from Great Britain and the Seychelles Islands, presented by Mr. H. Sidebottom, Cheshire, England, and a collection of parasites of fishes, transmitted by Prof. Edwin Linton, of Washington, Pa. A very interesting series of European parasites, comprising trematodes, cestodes, and nematodes, was deposited in the Museum by the Bureau of Animal Industry, Department of Agriculture.

To the Osteological collection were added a skeleton of the giant salamander, *Sieboldia japonica*, presented by the Imperial Museum of Tokyo; three skeletons of Harris's cormorant, *Nanopterum harrissi*, purchased from Mr. R. H. Beck, of Berryessa, Cal., and a skeleton of musk ox from Ellesmere Land, representing a species new to the Museum, from Mr. J. S. Warmbath, of Washington, D. C.

The National Herbarium has been enriched by a collection of about 1,400 plants from the Philippine Archipelago, contributed by the Philippine bureau of agriculture, and by another collection from the same locality received from the Royal Botanical Gardens, Kew, England. Mr. William R. Maxon, of the Museum staff, obtained a large collection of ferns and other plants during a collecting trip of about two months' duration in Jamaica. Dr. E. A. Mearns, U. S. Army, presented a large series of plants collected in the Yellowstone National Park, and Capt. John Donnell Smith, of Baltimore, Md., who has made extensive contributions to the Herbarium, continued his donations during the past year, transmitting a series of plants from the West Indies and Central America.

As in past years, the principal accessions to the geological collections were from the United States Geological Survey. Among the more important ones of the year were two series of minerals, rocks, and ores, constituting a portion of the exhibit made by the Survey at the expositions recently held in Buffalo and Charleston. An interesting lot of tourmalinitic quartz from Little Pipestone district, Montana, of which some of the specimens are covered on one side with parallel layers of amethysts of different hues, accompanied this material.

A valuable series of massive and cut polished stalactites and stalagmites from the Copper Queen mine was presented by Mr. James Douglas, of Bisbee, Ariz.

A specimen of pallasite, weighing 351 pounds, from Mount Vernon, Ky.; a mass of meteoric iron from Arispe, Mexico, weighing 116 pounds; a mass of meteoric iron from Persimmon Creek, in North Carolina, weighing 9 pounds, and a meteoric stone, weighing nearly 9 pounds, from Hendersonville, N. C., are among the most important additions to the meteoric collections.

A small piece of the only known specimen of footeite was donated by Mr. Warren M. Foote, of Philadelphia, and 35 very desirable minerals not previously represented in the Museum collection were obtained by purchase.

The largest and most valuable addition to the Division of Stratigraphic Paleontology was the second installment of the E. O. Ulrich collection of Paleozoic bryozoans, comprising about 7,500 specimens and 2,500 microscopic slides. The collection as a whole is the most extensive of its kind in existence and contains many unique specimens. About 14,000 corals, crinoids, mollusks and other invertebrate fossils were received from Prof. Carl Rominger, of Ann Arbor, Mich. Many of these have been figured and described in the reports of the geological survey of Michigan. The Andrew Sherwood collection of Pennsylvania Upper Devonic vertebrate and invertebrate fossils is also entitled to special notice. This collection was brought together

by Mr. Sherwood, and includes many choice slabs filled with large brachiopods and mollusks, besides about 3,000 small specimens.

The collection of vertebrate fossils was increased by several important additions, one of which, comprising the teeth of *Mastodon humboldtii* and *Mastodon cordillerum* and casts of mandibular rami, was received from the British Museum, London, England. Dr. H. J. Herbein, of Pottsville, Pa., contributed a slab of sandstone showing reptilian footprints, from Mount Carbon, Pa., and Mr. Whitman Cross, of the United States Geological Survey, collected and transmitted a tooth of *Cladodus formosus* (Hay) from Needle Mountains Quadrangle, Colorado.

About 500 specimens of Triassic plants, collected in Connecticut and Massachusetts by Mr. S. Ward Loper, of the United States Geological Survey, have been turned over to the Museum; a small series of fossil plants from the Permian of Ohio was donated by Mr. H. Herzer, of Marietta, Ohio, and about 80 specimens of Paleozoic plants were received with the Ulrich collection above mentioned.

Explorations.—Fewer explorations than usual were carried on last year directly by the Museum, owing to the scarcity of means for this purpose.

The fieldwork under the Bureau of American Ethnology, which yielded interesting collections of objects, since deposited in the Museum as before mentioned, was conducted by Mr. William H. Holmes, Mr. Gerard Fowke, and Dr. J. Walter Fewkes. Mr. Holmes visited the aboriginal hematite mines at Leslie, Mo., and Mr. Fowke an ancient quarry in Carter County, Ky., while Doctor Fewkes spent considerable time in Santo Domingo and Porto Rico.

The important explorations of Dr. William L. Abbott in Sumatra and the adjoining islands, as well as on the mainland of the Straits Settlements, have already been referred to under the heading of Additions to the Collections. These explorations, which are carried on entirely at the expense of Doctor Abbott, have now been in progress for several years, and through his generosity the National Museum has been the fortunate recipient of the very large and extremely valuable collections that he has made.

Mr. F. A. Lucas, with two others of the Museum staff, visited one of the stations of the Cabot Steam Whaling Company, on the coast of Newfoundland, in the interest of the St. Louis Exposition, for the purpose of securing as complete a representation as possible of a large sulphur-bottom whale. He was entirely successful, returning with a perfect skeleton of a specimen measuring about 78 feet long, and with molds of the exterior from which a cast of the entire animal will be made. These specimens, at the close of the exposition, will be returned and exhibited in the Museum.

Through the courtesy of the Geographical Society of Baltimore the Museum was enabled to send Mr. B. A. Bean and Mr. J. H. Riley with an expedition to the Bahama Islands, where they made collections of the fishes and land animals of that region.

Dr. H. G. Dyar and Mr. Rolla P. Currie, also of the Museum staff, accompanied an expedition to British Columbia under the auspices of the Carnegie Museum, and brought back with them a large and important collection of insects. Mr. Gerrit S. Miller, jr., collected mammals in Virginia, and Mr. William R. Maxon plants in Jamaica.

Mr. S. Ward Loper, of the United States Geological Survey, made for the Museum an interesting collection of Triassic plants in Connecticut and Massachusetts, and, through arrangements with the Director of the Survey, Hon. Charles D. Walcott, Mr. Charles Schuchert, of the Museum staff, spent several weeks in Virginia and Georgia with the special view of determining the geological horizons of the southern part of the Appalachians. Incidental to this study he collected many fossils. Several weeks were spent by Mr. R. S. Bassler in Ohio, Indiana, and Kentucky, collecting invertebrate fossils.

In connection with the Baldwin-Ziegler expedition to the Polar regions, a small collection of natural-history specimens obtained about Franz Josef Land was presented to the Museum by Mr. Ziegler. It is hoped that the second expedition now in progress under the same auspices will result in additional accessions from that little-known region.

Researches.—The Museum collections serve as the basis for a large amount of scientific work, as detailed each year in the full reports of the Museum, which also contain lists of the papers resulting from these studies. These investigations are carried on both in Washington and at different establishments throughout the country. The Museum assistants give to the classification of the collections as much time as can be spared from their duties as custodians. Specialists from the scientific bureaus in Washington and from elsewhere are frequent visitors at the Museum, coming for the purpose of consulting the collections or of conducting researches of greater or less extent. The number of specimens sent out to investigators during the year has amounted to more than 12,000.

Among those now engaged in the study of special groups in the direct interest of the Museum are Prof. Charles L. Edwards, of Trinity College, Hartford, who is at work upon the pedate holothurians; Prof. Hubert Lyman Clark, of Olivet College, Michigan, who has the apodal holothurians; Prof. C. C. Nutting, of the University of Iowa, who has nearly completed a monograph on the Sertularian hydroids; Dr. Charles B. Wilson, of the State Normal School, Westfield, Mass., who is studying the parasitic copepoda, and one of whose papers on the family Argulidæ was published during the year; and Prof. A. G. Mayer, scientific director of the museum of the Brooklyn Institute of Arts and Sciences, who is finishing the uncompleted studies of the late Prof. Alpheus Hyatt on the Museum collection of Achatinellidæ.

Among other well-known specialists to whom zoological material has been lent are Dr. J. A. Allen and Mr. Frank M. Chapman, of the American Museum of Natural History, New York City; Mr. Witmer Stone and Mr. J. A. G. Rehn, of the Philadelphia Academy of Natural Sciences, and Dr. D. G. Elliot, of the Field Columbian Museum.

About 400 orchids were sent to Mr. Oakes Ames, of North Easton, Mass., and about 300 specimens of *Rudbeckia* and the same number of *Coreopsis* to Mr. C. D. Beadle, of Biltmore, N. C.

The Department of Geology has contributed material to the United States Geological Survey and to various Bureaus of the Department of Agriculture for use in connection with current investigations; specimens of radio-active minerals have been furnished to Prof. George F. Barker, of the University of Pennsylvania; about 260 Tertiary insects were lent to Prof. S. W. Williston, of the University of Chicago, and 500 Carboniferous insects to Dr. Anton Handlirsch, of the Royal Austrian Museum, Vienna.

Exchanges.—In the act of 1846 founding the Smithsonian Institution, the exchange of duplicate specimens with other institutions was authorized as a means of enlarging the collections in the Smithsonian Museum. This practice was begun at an early date, and has been continued down to the present time. It has not, however, been carried on to the extent that the collections would permit, for the reason that the staff has never been large enough to classify the specimens to such a degree that even a fair part of the duplicates could be set aside from those which must remain as permanent records in the Museum. Nevertheless, very much has been done in this way and numerous exchanges were made during the past year. Furthermore, in accordance with acts of Congress, duplicate specimens not required for exchange, have been made up into sets and distributed to educational establishments throughout the country, thus promoting educational interests at a distance from the Museum.

The exhibition halls.—A number of collections and specimens recently received have been placed on exhibition, but, as intimated in previous reports, the installa-

tion of new material is made possible only by transferring other collections to storage or by crowding the exhibits so closely together as to render them practically useless to the public.

The gallery of the northwest court has afforded temporary accommodations for the ethnological material obtained from the Philippine Islands, while the other galleries assigned to the Department of Anthropology have been utilized in relieving the general congestion which of late years has become so noticeable throughout the Museum building. The large ethnological collections received from Dr. William L. Abbott and from the Museum-Gates expedition, with many others of equal importance, have been stored away for the present. Special attention has been paid to the labeling of the historical collections, and conspicuous labels now indicate the contents of the various halls, alcoves, and cases. The study collection of Eskimo objects has been rearranged and placed temporarily in storage cases in the northwest range. As it has been impossible to make the repairs called for in the hall devoted to Prehistoric Archeology, it has remained closed during nearly the entire year.

In the Department of Biology good results have been obtained by the rearrangement and refitting of cases, especially those containing the exhibits of mammals, insects, fishes, and marine invertebrates, and much progress has been made in labeling both the small American mammals and the Old World series. A new mounting has been made of the very beautiful Argus pheasants, which were presented by Dr. William L. Abbott some years ago, and it is now one of the most attractive of all the exhibition groups.

The geological halls remain much the same as last year because no additional space has become available, but there has been some expansion in the exhibit of fossil vertebrates, to which a specimen of *Claosaurus* will shortly be added, as well as the mounted skeleton of a mastodon. The cases containing the nonmetallic minerals and the geographic exhibit of economic minerals have been carefully cleaned and the specimens rearranged, while the case in the west-south range, in which the stratigraphic and historical collections are exhibited, has been reconstructed and the specimens have been reinstalled. A large number of labels and reference cards have been prepared, and some progress has been made in the preparation of the card catalogue of type material.

Visitors.—The total number of visitors to the Museum building was 315,307, and to the Smithsonian building 181,174, an increase in the first instance of about 81 per cent and in the latter of about 26 per cent over the previous year.

Meetings and lectures.—The use of the lecture hall was granted to the Biological Society of Washington for a series of five scientific lectures given between February 14 and March 14. The Naval Medical School and the Army Medical School also held their graduating exercises there on April 4 and 14, respectively, and the annual spring meeting of the National Academy of Sciences was held in the same place from April 21 to 23.

Publications.—Somewhat more than the usual number of publications were issued during the past year, and it is estimated that the distribution to libraries and individuals, both at home and abroad, amounted to about 45,000 volumes and separate papers.

The new publications of the year consisted of the Annual Report for 1900; the second volume of Mr. Ridgway's monograph on The Birds of North and Middle America; A List of North American Lepidoptera, by Dr. Harrison G. Dyar; volume 24 of the Proceedings, in bound form; the separate papers, 31 in number, constituting volume 25, and the first 27 papers of volume 26 of the Proceedings. A pamphlet of instructions to collectors of anthropological objects, with special reference to the Philippine Islands and other insular possessions, prepared by Mr. William H. Holmes and Prof. O. T. Mason, was issued as Part Q of Bulletin 39.

The sundry civil act for 1903 provided for the transfer of the management of the Contributions from the United States National Herbarium from the Department of Agriculture to the National Museum. Under this provision two former volumes, Numbers II and VII, were reprinted by the Museum, namely, Botany of Western Texas, by Prof. J. M. Coulter, and Systematic and Geographic Botany and Aboriginal Uses of Plants, by Messrs. Coulter, Rose, Cook, and Chesnut. Of the current volume, Number VIII, parts 1, 2, and 3, were issued, their titles being as follows: Studies of Mexican and Central American Plants, by Dr. J. N. Rose; Economic Plants of Porto Rico, by Prof. O. F. Cook and Mr. G. N. Collins; and A Study of Certain Mexican and Guatemalan Species of *Polypodium*, by Mr. William R. Maxon.

A number of Museum papers greatly in demand, the editions of which had become exhausted, were reprinted. Among them were the first volume of Bulletin 47, by Doctors Jordan and Evermann, entitled "Fishes of North and Middle America;" Doctor Stejneger's paper on the Poisonous Snakes of North America; Doctor Dall's Preliminary Catalogue of the Shell-bearing Marine Mollusks and Brachiopods of the Southeastern Coast of the United States; Mr. Ridgway's monograph on the Humming Birds, and several of the pamphlets of instructions to collectors from Bulletin No. 39.

Twelve papers prepared by members of the staff, based upon material in the Museum, were by permission of the Secretary, printed in publications other than those of the National Museum.

Library.—The increase of the Museum library during the past year has been mainly due to two very important gifts—the Hubbard and Schwarz, and the Dall donations. The former collection, consisting of 300 books and 1,500 pamphlets, was brought together by Mr. G. G. Hubbard and Mr. E. A. Schwarz (custodian of Coleoptera in the Museum) while carrying on their studies more or less conjointly, and forms an accessory to their large collection of insects presented to the Museum several years ago. It is an entomological library, with special reference to the American Coleoptera. The contribution by Mr. William H. Dall, honorary curator of Mollusks, comprises about 1,600 bound volumes and about 2,000 pamphlets on the molluska, a special library of great value, which has been accumulated during many years of research. It is accompanied by a card catalogue covering the literature of Conchology, both recent and fossil, up to about 1860.

The aggregate of additions to the library for the year amounted to 3,161 books, 3,260 pamphlets, and 303 parts of volumes.

Expositions.—Much progress has been made during the year in connection with the preparation of the exhibits for the Louisiana Purchase Exposition. An especially noteworthy feature will consist of the complete skeleton and a cast of the exterior of a sulphur-bottom whale which measured 78 feet long when caught. It was obtained at one of the whaling stations on the Newfoundland coast and was roughly prepared for shipment to this country by members of the Museum staff.

There will be several striking groups in ethnology, arranged by Mr. William H. Holmes, who is also preparing a model of one of the great Maya temples in southern Mexico. A special effort is being made by Dr. F. W. True, the representative of the Institution and the Museum, to produce a satisfactory display of American animals mounted in accordance with the latest methods of taxidermy. The geological exhibit, which is to include one or more of the huge fossil Dinosaurs, is being prepared under the direction of Dr. George P. Merrill.

Respectfully submitted.

Richard Rathbun,

Assistant Secretary in charge of the U. S. National Museum.

Mr. S. P. Langley,

Secretary of the Smithsonian Institution.

August 1, 1903.

Appendix II.

REPORT OF THE BUREAU OF AMERICAN ETHNOLOGY.

Sir: I have the honor to submit the following report on the operations of the Bureau of American Ethnology for the fiscal year ending June 30, 1903, conducted in accordance with the act of Congress making provision for continuing researches relating to the American Indians under the direction of the Smithsonian Institution. The work has been carried out, in the main, in accordance with the plan of operations submitted by Director Powell on May 20, 1902, and approved by the Secretary May 23, 1902.

The death of Maj. J. W. Powell, Director of the Bureau, occurred at Haven, Me., September 23, 1902. This event profoundly affects the interests of the Bureau, and closes an epoch of exceptional importance in the history of the science of man. The wisdom of the foundation laid by Director Powell is everywhere recognized, and the impetus given to anthropological studies by his work must continue to be felt long after the present initial stage of the science has ripened into the full knowledge which shall regulate and direct the future development of the human race.

During the somewhat prolonged period of Director Powell's illness the administrative work of the Bureau devolved upon Mr. W J McGee, ethnologist in charge, who was Acting Director at the time of Major Powell's death. On October 11, 1902, Mr. W. H. Holmes, head curator in the Department of Anthropology, United States National Museum, was appointed Chief of the Bureau and assumed charge of the office October 13.

The research work of the Bureau has been carried on by a permanent force of 9 scientific employees, while a number of temporary assistants have been engaged for brief periods in the office and among the western tribes. During the year 5 members of the staff have spent a portion of their time in the field. The regions visited include Georgia, Alabama, Kentucky, Indiana, Minnesota, Missouri, Kansas, Iowa, Oklahoma, Indian Territory, New Mexico, Arizona, Wyoming, Idaho, California, Porto Rico, and Santo Domingo.

The researches have been of exceptional importance and have dealt with numerous branches of primitive culture and history, practical questions having been kept as much as possible in view. The completion of reports on field exploration and the preparation of papers dealing with special problems have claimed much attention, and every effort has been made to bring up to date and submit for publication researches that have been maturing during the previous years. The preparation of data for a dictionary of the Indian tribes has been a principal feature of the year's work, claiming the attention of all available members of the Bureau staff and employing the services of a number of special students. Detailed reference to this work is made farther on in this report.

The range of the scientific work has been wide but has not extended, save incidentally, to all departments of Anthropology. Philology, sociology, sophiology, technology, and æsthetics have received attention by those conducting investigations among the tribes in the field and by those engaged in office researches, but somatology and psychology have received no systematic attention.

The nonscientific work of the Bureau, which includes the library, the photographic laboratory, the editorial, and the general clerical work has engaged ten persons aside from the chief administrative officer, and on the whole has progressed favorably, many changes having been made in method and routine, especially toward the close of the fiscal year.

For the better understanding of the work of the year and the conditions affecting the present affairs of the Bureau, considerable data dealing with history, statistics, and routine have been introduced into this report.

RESEARCH WORK.

The Chief prosecuted archæological researches at a number of points in the eastern section of the United States. Previous to October 13 he was engaged, with the assistance of Mr. Gerard Fowke, in making examinations of the fossil bone beds at Kimmswick, Mo., with the view of determining whether there was satisfactory evidence that man was contemporaneous with the mammoth and the mastodon in that region; but no traces of man were found in direct association with the fossil remains. Examinations of aboriginal flint quarries and sites of stone-implement manufacture were made in southern Indiana and in eastern Kentucky. In October explorations were undertaken at Lansing, Kans., with the view of determining the age of the human remains found embedded in loess-like formations near that place. The formations were extensively trenched by Mr. Fowke, under the direction of the Chief of the Bureau, and the conclusion was reached that the remains were of exceptional antiquity for America, but that they could not with certainty be assigned to a definite geological horizon and that they were probably of post-Glacial time. In April the Chief paid a visit to Leslie, Mo., for the purpose of studying certain traces of ancient operations reported to occur in an iron mine near that place. Very interesting phenomena were encountered, the ancient aborigines having penetrated the ore body in many directions and to surprising depths, the purpose being, apparently, to obtain the red and yellow iron oxides for paint. Many hundreds of mining tools of stone were found in the ancient tunnels. Early in May a trip was made to Georgia and Alabama for the purpose of examining quarry sites and caverns occupied in ancient times by the aborigines.

Reports have been prepared on the explorations at Lansing, Kans., and at Leslie, Mo. The first of these researches deals with the important and ever-recurring question of the antiquity of man in America. It has been the aim of the Bureau, and especially of the present Chief, to occupy conservative ground with respect to this subject, and to so scrutinize the discoveries and reputed discoveries reported from time to time that erroneous interpretations should not prevail. The purpose of the excavations made at Lansing was to expose the formations containing the human remains so fully that geologists of all ways of thinking might study them to advantage, thus preventing the adoption of conclusions based on inadequate observations. The Leslie iron mine study has an interesting bearing on the technic and industrial history of the tribes. It has been a matter of much surprise, as the investigations of the ancient mining and quarrying have progressed, that the aborigines, seemingly so nonprogressive and shiftless, should have conceived and carried out really great enterprises. The technical knowledge and skill displayed are of a low order indeed, but the work accomplished indicates remarkable enterprise and persistence, and demonstrates the existence of native capacity of high order.

Mr. W J McGee, ethnologist in charge, continued as Acting Director until October 13. During this period he prepared the annual report for the preceding year, made a hasty archæological and ethnological reconnoissance in Minnesota, and in September visited Baddeck, Nova Scotia, whence he was called to the deathbed of Major Powell in Haven, Me. In December he visited Mexico with the view of arranging for an expedition to the island of Tiburon, but in this he was not successful. En route

he stopped over a day in New Mexico to visit some ancient ruins near the village of Cuchilla. On returning from Mexico Mr. McGee suffered from a fever which prevented active work for a period of about three months.

In July, August, and September, Dr. J. Walter Fewkes was occupied in the preparation of the text and illustrations of an account of a reconnoissance made in Porto Rico during May and June of the previous fiscal year. This report, which was intended to be a résumé of what is known of the prehistoric inhabitants of Porto Rico, was finished in October and placed in the hands of the Acting Director, who transmitted it to the Public Printer as Bulletin 28. Considerable time in these months was likewise given by Doctor Fewkes to correcting proofs and arranging the plates of his memoir on a series of native pictures of Hopi katcinas, or ancestor-gods, for the Twenty-first Annual Report of the Bureau. Doctor Fewkes left Washington for a second expedition to the West Indies in the middle of November, remaining there over five months and visiting the islands of Porto Rico and Santo Domingo. The collection of prehistoric objects made on this trip numbers over 1,000 specimens, 110 of which were obtained by purchase in Santo Domingo, the remainder by exploration and purchase in Porto Rico. Not only is this collection numerically the largest which has been brought to the Smithsonian Institution from Porto Rico and Santo Domingo at any one time, but it is also one of the most significant on account of its wealth in typical forms previously unrepresented in the Museum.

Doctor Fewkes was able to determine by excavations that the inclosures surrounded by aligned stones and called by the natives "juegos de bola" were made by the aborigines of the island for ceremonial dance places, and that neighboring mounds are prehistoric cemeteries. The determination of the burial places of the prehistoric Porto Ricans and their discovery in numbers are believed to be the most important results of Doctor Fewkes's field work in Porto Rico. With this information to guide him, the archæologist will have little difficulty in the future in adding to existing collections of prehistoric objects from Porto Rico and in placing them in their proper categories.

Doctor Fewkes made excavations in a cave called "Cueva de las Golondrinas," situated near the town of Manatí, and found large quantities of Indian pottery and a few other objects of aboriginal manufacture. All the evidence collected indicates that while the aborigines had frequented this cave for a long time, the culture of the earlier and later occupants was practically identical. After his return to Washington in May, Doctor Fewkes was occupied in cataloguing the objects collected during the winter and in preparing a preliminary report on them. He was permitted to withdraw the account of his previous year's explorations, which had been transmitted to the Public Printer as a bulletin with a view of incorporating with it the new material obtained on this second visit to the island. The valuable results of the two years' work will thus appear in monographic form in a forthcoming annual report.

The researches of Doctor Fewkes furnish much material of value bearing upon questions of science and history. Of first importance is the decided advance made toward identifying and rehabilitating the unfortunate peoples of the West Indies, swept almost without record from the islands during the early years of Spanish colonization. Considerable information regarding their physical characters and manner of life has been gained, and various branches of culture are illustrated by the collections, while definite notions of the origin, burial customs, and arts and industries of the island peoples are for the first time conveyed to the world of science. Doctor Fewkes has thus shed light on a significant and important chapter of aboriginal American history.

The months of July to November, inclusive, were spent by Mrs. M. C. Stevenson in researches among the Zuñi Indians, the special objects being a comparative study of the peoples of the Southwest and a collection of the ethnoflora of Zuñi. Some years ago Mrs. Stevenson observed that the prayers of one of the Zuñi rain priests

were sung in the Sia tongue, and that one of the esoteric fraternities sang in Piman, but it was not until her last visit to Zuñi that she learned that all of the thirteen esoteric fraternities used other languages than their own in their ceremonies. It is difficult to catch the words of an aboriginal choir singing to the accompaniment of rattles and drums, especially when the mind is absorbed in noting the ritual rather than the words employed. But during the last season, having in view a comparative study of the Pueblo Indians, and knowing that at least one fraternity employed a foreign tongue, Mrs. Stevenson closely observed this feature of the ceremonies and made special inquiries of the priests and theurgists, thus determining the remarkable fact that this was true of all. Several reasons could be advanced for this use of strange languages, but it remains for future investigation to acquaint us fully with the facts.

Mrs. Stevenson makes the important observation that, although the ceremonies which she describes in her monograph were regularly practiced during the first decade and a half spent by her in their study and were faithfully observed in every detail, they have since been gradually changed and in some instances have been abandoned. It would thus appear that these researches were not undertaken a moment too soon.

In the main the results of the year's work in Zuñi have been incorporated in the monographic studies of the Zuñi people prepared by Mrs. Stevenson during the previous years. The final work is now in the editor's hands and will soon be submitted for publication. Mrs. Stevenson's familiarity with the language of the Zuñis, the confidence with which she has inspired them, the deep insight she has obtained into the philosophical and religious meaning of their ceremonies, and her intimate knowledge of their sociology peculiarly fit her for the presentation of a monograph on this people.

The herbarium of edible, medicinal, and fetishistic plants collected by Mrs. Stevenson over an area 110 miles north and south and 60 miles east and west from Zuñi, contains about 200 specimens. Among the many interesting varieties are a narcotic, *Datura stramonium*, a specific for hemorrhage, *Ustilago*, and what the Zuñi claim to be their native cotton, *Esculapia Mexicana*. The fiber of the latter is made at the present time into a cord for the more sacred objects used by the rain priests, and the Zuñis claim that all of their cotton fabrics were woven of this plant before the advent of the Spaniards. Acknowledgments are due to Dr. F. V. Coville, Botanist, Department of Agriculture, and Dr. J. N. Rose, Assistant Curator, U. S. National Museum, for their courteous assistance in providing Mrs. Stevenson with facilities for preserving the plants and also for the classification of the collection.

At the beginning of the fiscal year Mr. James Mooney was in the field in western Oklahoma, engaged in the prosecution of researches among the Kiowa and Cheyenne tribes in the joint interest of the Bureau of American Ethnology and the Field Columbian Museum under an agreement made in the preceding year. Except during two brief visits to Washington, in September and in November, 1902, Mr. Mooney devoted the entire year to researches relating to the social customs, religion, and art of the tribes, especial attention being given to investigations of the heraldry system of the Kiowa and Kiowa-Apache tribes as exemplified in the old-time shields and decorated tipis. His work comprised the preparation of a full series of shield and tipi models on a suitable scale, together with related investigations and collections. The heraldry investigation and the model series for the confederated Kiowas and Kiowa-Apaches are nearly finished and the latter is expected to constitute part of the Smithsonian exhibit at the forthcoming Louisiana Purchase Exposition. The complete model series may be estimated to contain 150 shields and 40 tipis for the Kiowas and confederated Apaches, and a somewhat smaller number for the Cheyennes. In April Mr. Mooney shifted his base of operations from Mount Scott, in the Kiowa country, to a station near Bridgeport, in the Cheyenne country, about 100 miles north, and has since been moving about among the widely separated Cheyenne camps.

Some weeks were devoted to a practical study of the hide-dressing process in all its stages in connection with the making of a full-size skin tipi. This important industry is thus for the first time placed fully on record. At the close of the present year Mr. Mooney was preparing to attend the great annual sun dance of the Cheyennes, to be held about the middle of July.

In addition to the research work referred to above, Mr. Mooney has assisted, both in the field and during his brief stay in the office, in preparing material for the Dictionary of Indian Tribes, in course of preparation by the Bureau.

The heraldry studies of Mr. Mooney have opened up a field entirely new to American ethnology, and are expected to contribute materially to our knowledge of many questions heretofore imperfectly understood in relation to the social and military organization, heredity laws, war customs, tabu system, and religious symbolism of the Plains tribes. The urgency of the work may be judged by the fact that of perhaps 300 shields in possession of the Kiowas a generation ago only 8 are now known to be in existence (4 of which have been obtained by Mr. Mooney for the National Museum), while more than half the information gained upon the subject came from old men who have passed away since the investigation began.

During the year Dr. Cyrus Thomas, ethnologist, was engaged mainly on the Dictionary of Indian Tribes, under the supervision of Mr. F. W. Hodge. In the early months he made a final examination of the data relating to the Algonquian family, and later took up the Siouan, Muskhogean, Timuquanan, and Natchesan stocks. Brief articles on a number of the leading subjects intended for introduction into the dictionary, such as Agriculture, Mounds, Mound-builders, Government, and numerous biographical sketches of prominent Indians, have been prepared by Doctor Thomas. He has thus contributed greatly to the interests of the Bureau in a practical way, putting in final and concise form much of the knowledge accumulated during his thirty years of service in his chosen field.

Doctor Thomas has been largely employed during preceding years, in direct association with Major Powell, in the important work of compiling a list of linguistic families, languages, and dialects of the tribes of Mexico and Central America, and the manuscript of this work, comprising some 200 typewritten pages, was submitted by him at the close of the present year.

At the beginning of the fiscal year Mr. J. N. B. Hewitt was engaged in the work of making an interlinear translation of a version of the Onondaga (Iroquoian) cosmologic myth, obtained in the field in 1900 from Mr. John Arthur Gibson, an intelligent and gifted Seneca priest. This text is by far the longest and fullest of the five versions of this myth recorded by Mr. Hewitt during several field seasons. Two of these texts are Seneca, two are Onondaga, and one is Mohawk. The Mohawk text, related by Mr. Seth Newhouse, the shorter Onondaga text, told by John Buck, and the longer Seneca text, told by John Armstrong, were sent to press in the previous fiscal year. The longer Onondaga text contains more than 44,000 words in the Onondaga dialect, to about one-third of which an interlinear translation has been added. The first draft of a free translation of it was completed in October of the previous fiscal year. This manuscript will be ready for the press as soon as the interlinear translation is completed and the free translation is revised. With it will be submitted the shorter Seneca version, which is practically ready for the press.

Later in the year much work was done on portions of the ritual of the Condoling Council of the League of the Iroquois. A free translation was made of the Onondaga version of the so-called "Fourteen Matters" and also of the Mohawk version of the "Address of Welcome" of the Brother Mourning Nations. The "Chant of Lamentation," requiring more than an hour to intone, was typewritten ready for interlineation. This work has enabled Mr Hewitt to ascertain approximately what is yet needful to complete his projected monograph on the Condoling Council of the League of the Iroquois.

In September Mr. Hewitt, assisted by the Rev. Jesse Kirk, an educated and intelligent Klamath quarter-blood Indian, undertook the special study of the system of blood relationships and affinities among the Klamaths of the Lutuamian linguistic family to ascertain whether or not these people have a clan system. This was done by means of two charts, one for the paternal and the other for the maternal lines of descent. It was shown by this study that the Klamaths have no clan system such as that prevailing among the Iroquois. An extensive vocabulary of Klamath vocables was also obtained from the Rev. Mr. Kirk, covering 57 manuscript pages. Mr. Hewitt also devoted much time to work in connection with the Dictionary of Indian Tribes, furnishing, among other contributions, the articles "Adoption," "Confederacy," and "Attakapan Family."

During the year Mr. Hewitt's regular research work has been interfered with to a very considerable extent by duties imposed in connection with the official correspondence of the Bureau. Many communications were received calling for information regarding the native languages, especially the significance of names and the interpretation of phrases and sentences, and these were for the greater part referred to Mr. Hewitt for report. Besides this a number of manuscripts forwarded for examination or for purchase have been placed in his hands for expert consideration.

In past years Mr. Hewitt has taken some part in the care of the great collection of manuscripts in the Bureau vaults, and toward the close of the present year he was appointed custodian of manuscripts. In this capacity he has again taken up the work of identifying, classifying and cataloguing these documents—a work of no little difficulty and requiring much time.

Dr. John R. Swanton was engaged for the greater part of the year in copying and translating texts obtained by him from the Haida Indians of Queen Charlotte Islands, British Columbia, during the winter of 1900–1901. There are two series of these texts taken in the dialects of Skidegate and Masset, respectively. Of the Skidegate series there are 75 texts (one-third of which are war stories), covering about 360 typewritten pages, and of the Masset series about 90 texts, covering about the same number of pages. These texts will be ready for publication early in the next fiscal year.

Doctor Swanton has also been engaged in the preparation of a grammatical study of the Haida language, which, while it is not exhaustive, will cover all essential points. He has also in hand a dictionary of the Haida language.

Doctor Swanton has assisted Mr. Hodge in the compilation of the Dictionary of Indian Tribes, and has revised, copied, and arranged all the descriptive material for the Chimmesyan, Koluschan, Salishan, Skittagetan, Takilman, and Wakashan linguistic families.

Dr. Albert S. Gatschet has continued his linguistic work, giving principal attention to the completion of a work on Algonquian texts, including the Peoria, Miami, and Wea dialects. He has also made some progress in the preparation of a Peoria dictionary and grammar, and in addition has rendered substantial aid in furnishing linguistic data called for by correspondents of the Bureau.

Dr. Frank Russell, ethnologist, spent most of the previous year among the Pima Indians of Arizona, and on the return journey paid a brief visit to the Muskwaki tribe in Iowa, reaching Washington in July. The report on his researches will appear in the Twenty-fourth Annual Report of the Bureau under the title "The Pima Indians of Arizona." His active connection with the Bureau ceased on October 30, but certain unfinished portions of the work were completed subsequently.

Dr. Stewart Culin, curator of anthropology in the museum of the Brooklyn Institute, has made progress in the preparation of a monograph on native American games which has been on hand for some years. It is planned to have it appear in the Twenty-fourth Annual Report.

In September Mr. R. H. Partridge was commissioned by the Acting Director to

visit New Mexico for the purpose of mapping certain ancient ruins situated in the valley of the Rio Hermoso, Socorro County. A month was spent in the work, and the map produced and a brief report descriptive of the exploration have been placed in the Bureau archives.

Dr. Albert E. Jenks, ethnologist, on furlough from the Bureau and connected with the Bureau of Non-Christian Tribes in the Philippine Islands, has communicated some details of a successful expedition conducted by himself among the Bontoc Igorrotes of northern Luzon. About the close of the year he became acting chief of the Bureau of Non-Christian Tribes, Doctor Barrows, the chief, having been appointed commissioner of education for the islands.

Under the immediate direction of Dr. Franz Boas, honorary ethnologist, important linguistic studies were made by Mr. H. H. St. Clair, 2nd, among the Ute, Shoshoni, and Comanche tribes. Numerous texts, grammatical notes, and vocabularies were collected, and in parts of this work the phonograph was used with success. The instrument was employed for recording the dictation of old men, and then the record was repeated slowly by interpreters. During the winter months Mr. St. Clair assisted Doctor Boas in the office, carrying forward various linguistic studies. In addition, Mr. St. Clair continued work on a Chinook dictionary, on which considerable progress had previously been made, and in June, 1903, he began work among certain tribal remnants in Oregon, more particularly the Alsea, Coosa, and Takilma.

Under Doctor Boas's supervision Mr. William Jones continued his linguistic work among the Sauks and Foxes. He has made a large collection of texts, all of which have been copied, and has also elaborated a detailed grammar of the language of these tribes. He has succeeded in carrying out the analysis of the Algonquian language in a much more satisfactory manner than did any of the older authors, such as Baraga, Howse, Cuoq, and Lacombe. It is expected that the manuscript of his grammatical studies will be completed by the end of the present calendar year. In the spring of 1903 Mr. Jones made investigations of the language of the Kickapoos, obtaining a considerable amount of linguistic material from among that tribe.

Besides directing the work of these assistants, Doctor Boas has continued his investigation of the grammar of the Tsimshian and Chinook languages.

The ripening of linguistic studies in America initiates a new era in this branch of research. Powell gave great impetus to the work, and numerous other students have devoted their energies assiduously to the important task of recording and classifying the American languages and applying the results to the elucidation of the history of languages and peoples. The ultimate object of the work conducted under the direction of Doctor Boas is a morphological classification of the languages of America. The enumeration of linguistic stocks published by Major Powell in the seventh annual report of the Bureau, is based entirely on vocabularies, many of which are very brief. By means of the study of the morphology of languages more remote relationships can be traced and the results of the lexicographer's comparisons can be checked. The grammatical studies that are carried on at present will therefore serve to elucidate many of the obscure parts of the earlier history of our country and the significance of the multitude of languages of California and the lower Mississippi region. The work is being done in systematic cooperation with investigators not connected with the Bureau. Among these are Dr. A. L. Kroeber, of the University of California, Dr. Roland B. Dixon, of Harvard University, and a few other students who are collecting material in California, partly for the University of California, partly for the American Museum of Natural History. Up to the present time the Bureau has taken up, in connection with this work, morphological studies of the languages of the northwest coast and of the Siouan, Shoshonean, and Algonquian stocks, three of the largest on our continent. The work has so far advanced that it is

proposed to prepare at once a handbook of the American languages as a preliminary publication.

The Bureau has had under way for some years the transcription of the Diccionario de Motul, a manuscript Maya-Spanish dictionary, borrowed from the library of the University of Pennsylvania. The copy is intended for the use of Señor Andomaro Molina, of Merida, Yucatan, who is engaged in compiling a Maya-English dictionary to be published by the Bureau. The transcription was in the hands of Miss Jessie E. Thomas, librarian of the Bureau, but her untimely death in January brought the work to a close. The dictionary was returned to the university library on March 15, as previously arranged, but permission has since been granted to bring it again to Washington when a competent copyist is found.

An important feature of the work of the year has been the preparation of material for a dictionary of the Indian tribes. It was the Secretary's wish that this undertaking should be carried rapidly to completion, and Mr. F. W. Hodge, formerly of the Bureau, but now connected directly with the parent Institution, was detailed to take charge of the work. Mr. Hodge arranged to spend the afternoon of each day at the Bureau, and was thus able to personally direct the work, a report on which is here presented.

DICTIONARY OF INDIAN TRIBES.

At the time of the early exploration and settlement of North America there were encountered many Indian tribes varying in customs and speaking diverse languages. Lack of knowledge of the aborigines and ignorance of their languages led to many curious errors on the part of the early explorers and settlers; names were applied to the Indians that had no relation whatever to those by which they were aboriginally known; sometimes nicknames were bestowed, owing, perhaps, to some personal characteristic, fancied or real; sometimes there was applied the name given by another tribe, which was often opprobrious; frequently an effort was made to employ the designation by which a tribal group knew itself, and, as such names are often unpronounceable by an alien tongue and unrepresentable by a civilized alphabet, the result was a sorry corruption, varying as the sounds were impressed on English, Spanish, French, Dutch, Russian, or Swedish ears, or as they were recorded in many languages, only to be as grossly corrupted when the next traveler appeared.

Sometimes, again, bands of a single tribe would be given distinctive names, while clans or gentes would be regarded as independent, autonomous groups to which separate tribal designations were likewise applied. Consequently, in the literature of the American Indians, which is practically coextensive with the literature of the first three centuries of the New World, thousands of tribal names are encountered, only a small proportion of which are recognizable at a glance; therefore, one of the most practical and important studies which was undertaken at the inception of the work of the Bureau was the classification of these names with the view of their publication as an Indian synonymy. As time passed, however, the scope of the work was enlarged, for, as the studies of the Bureau were prosecuted, a large amount of information in regard to the tribes, both past and present, was gained, so that it was deemed desirable to make of the work a cyclopedia or dictionary of the Indians, containing tribal synonyms.

The work continued at intervals during several years, most of the scientific corps, particularly Mr. James Mooney, being engaged in the compilation, under the general supervision of Mr. H. W. Henshaw, until 1891, when, owing to failure of health, Mr. Henshaw was compelled to relinquish ethnologic work. Later the task was assigned to Mr. Hodge, who continued it, so far as his other duties permitted, until early in 1901, when he was transferred to the office of the Smithsonian Institution. The work was continued, with many interruptions, until November of the present

fiscal year, when, as has been stated, Mr. Hodge was again assigned to the task. In accordance with the Secretary's wish, the scope of the work was enlarged to include not only descriptions of the Indian stocks, confederacies, tribes, subtribes, phratries, bands, clans, gentes, and settlements, as previously planned, but also biographies of the most noted Indians, sketches of the native manners, arts, and customs, and a list of Indian words incorporated into the English language.

The facilities of the Bureau were immediately made available, most of the scientific corps devoting at least a part of their time to the work, while the services of others not officially connected with the Bureau were enlisted in directions in which their special knowledge would be advantageous. To this end the Athapascan stock was assigned first to Dr. Washington Matthews, whose ill health unfortunately compelled him to relinquish it, when it was given to Dr. J. H. McCormick; the Attacapan, Beothukan, Iroquoian, and Uchean stocks were assigned to Mr. J. N. B. Hewitt; the Chimakuan, Chinookan, Kalapooian, Kusan, Lutuamian, Shahaptian, Takilman, Waiilatpuan, and Yakonan to Dr. Livingston Farrand; the Chimmesyan, Koluschan, Salishan, Skittagetan, and Wakashan to Dr. John R. Swanton; the Calfornian stocks to Dr. A. L. Kroeber and Dr. Roland B. Dixon; the Algonquian, Chitimachan, Karankawan, Muskhogean, Natchesan, Shoshonean, Siouan, and Timuquanan to Dr. Cyrus Thomas; the Caddoan to Mr. James Mooney; the Eskimauan, to Dr. J. H. Bair, and the Kitunahan to Dr. A. F. Chamberlain, while the Piman and the Pueblo stocks were undertaken personally by Mr. Hodge. At the close of the year the work on these stock and tribal descriptions had been well advanced, most of the important as well as a number of the smaller linguistic groups being entirely ready for final editorial revision. Owing to pressure of other duties, a number of the specialists not officially connected with the Bureau required more time than was expected, so that some of the outstanding material can not be finished as soon as was desired.

In accordance with the plan of enlargement of the scope of the dictionary outlined by the Secretary, a schedule of all the subjects thought to be necessary was prepared and they were assigned to the specialists to be succinctly written. Those who have been engaged in this part of the work are Mr. W. H. Holmes, Mr. F. W. Hodge, Dr. Cyrus Thomas, Mr. J. N. B. Hewitt, Dr. A. F. Chamberlain, Mr. James Mooney, Prof. O. T. Mason, Dr. Walter Hough, Miss Alice C. Fletcher, Dr. Washington Matthews, Dr. J. R. Swanton, Mr. Joseph D. McGuire, Dr. Frank Russell, and Mr. Stewart Culin. At the close of the fiscal year nearly all of the 300 or more articles thus assigned were completed, as was the bibliography of works cited in the tribal descriptions of the dictionary. This latter was prepared by Mr. McGuire.

For several weeks Mr. Hodge has been engaged in putting in final form the first half of the material for the first of the proposed two volumes. The first of the Algonquian descriptions (A to M), recorded on about 10,000 cards, were more than half revised for the printer by the close of June, and many more stocks were awaiting similar editorial treatment.

EXPOSITION WORK.

Early in the year an allotment of $2,000 was made by the Smithsonian Institution, from funds placed at its disposal by the Government board of the Louisiana Purchase Exposition, to be used by the Bureau in preparing an exhibit for the exposition. It is arranged that this exhibit shall comprise ethnological and archæological collections illustrative of the research work of the Bureau, and instructions have been given to members of the staff in the field to take up the work. Progress has been reported by Dr. J. W. Fewkes, who will illustrate his researches in the West Indies; by Mrs. Matilda Coxe Stevenson, who will collect specimens illustrating Zuñi arts and customs, and by Mr. James Mooney, who has in hand a series of exhibits designed to represent the heraldic systems of the Plains Indians.

ILLUSTRATIONS.

The illustrations are a most important feature of the research and publication work of the Bureau. They consist of drawings, photographs, rubbings, engravings, etc., derived from many sources, and either used in the illustration of papers or filed for reference. The photographic work includes the making of photographs of all visiting Indians, copying pictures and maps, and photographing specimens.

Mr. DeLancey Gill has continued in charge of illustrations, the volume of work being about the same as in previous years. The preparation of illustrations, the criticism and revision of engravers' proofs, and the photographic work have been carried on in the usual manner. Illustrations for Doctor Fewke's paper on his Porto Rican studies, consisting of 25 original drawings and photographs, were prepared and sent with the manuscript to the Public Printer. Engraved proofs of 330 drawings and photographs, intended for use in the Twenty-second Annual Report, have been received from the Public Printer during the year, and have been criticised and corrected. The printed editions of 107 colored plates, representing nearly 1,000,000 impressions, to be used in the Twenty-first and Twenty-second Annual reports, have been examined by Mr. Gill and the imperfect work rejected. Drawings to the number of about 200, intended for forthcoming reports by Mrs. M. C. Stevenson and Dr. Stewart Culin, were executed by contract under the supervision of the authors. The preparation of illustrations for reports following the Twenty-third was taken up toward the close of the year.

The photographic work has progressed satisfactorily. Six hundred and forty-six $6\frac{1}{2}$ by $8\frac{1}{2}$ inch negatives have been made 123 of which were exposed in the field by Dr. Frank Russell and developed in the office laboratory. About five hundred 4 by 5 inch films were exposed in the field by Dr. Fewkes, and also developed in the office laboratory, and a large number of portraits of visiting Indians were made during the year. In all, 1,146 negatives were added to the collection and 1,341 prints were made.

Detailed plans by Mr. Gill of three of the great ruined buildings of Mexico, the temple of Xochicalco, the temple of the Columns, Mitla, and the House of the Governor, Uxmal, were prepared for use in constructing models of the buildings for the Louisiana Purchase Exposition exhibit of the Smithsonian Institution.

COLLECTIONS.

For a number of years previous to the separation of the Bureau of Ethnology from the Geological Survey, and also since the separation took place, the Bureau has made extensive collections of objects illustrating its researches and forming the basis for important studies. The collections have usually been catalogued on arrival at the Bureau, and after serving their purposes for study and illustration have been transferred to the United States National Museum, where they have been recorded and properly accredited to the Bureau.

During the year important collections have been made as follows: Archæological collection from Santo Domingo and Porto Rico, by Dr. J. W. Fewkes, 1,210 specimens; archæological collection from an aboriginal hematite mine in Missouri, by W. H. Holmes and Gerard Fowke, 160 specimens; collection of flint implements from Indiana and Kentucky, by Gerard Fowke, many thousands of specimens; ethnological collection from Zuñi Pueblo, Arizona, by Mrs. M. C. Stevenson, 220 specimens. These have been transferred to the National Museum along with numerous other collections found in the Bureau offices and in storage. The latter include a large collection from the Maine coast shell heaps, made by Mr. F. H. Cushing, 3,058 specimens; an important collection of ethnological material from the Pima Indians of Arizona, made by Dr. Frank Russell, 324 specimens, and numerous small collections and single specimens. These collections have been accompanied by all available data

relating to them, and are so placed at the Museum as to be convenient for study by the various collectors in preparing their reports and by students generally.

MANUSCRIPTS.

Of peculiar value and interest are the manuscripts brought together in the archives of the Bureau. They number upward of 1,600 and relate chiefly to the Indian languages. Three hundred and thirty-two of these documents were transferred to the Bureau on its organization by the Smithsonian Institution. Many others have been presented to the Bureau since that time, while a large number have been purchased from the authors. Not a few have been prepared by employees of the Bureau, and, because fragmentary or not fully elaborated, have been filed awaiting completion and for reference. A valuable body of linguistic data is thus preserved and available for the use of students. Besides the linguistic material many miscellaneous manuscripts and documents have accumulated. A few of these are historical, but the majority relate to the aborigines. These manuscripts are kept in two fireproof vaults in the main office and have been recently placed under the custodianship of Mr. J. N. B. Hewitt, ethnologist.

PUBLICATIONS.

History of the series.—When the United States Geographical and Geological Survey of the Rocky Mountain Region was discontinued, by act of Congress approved March 3, 1879, it had published two volumes (1 and 3) of a quarto series of Contributions to North American Ethnology. The same act made an appropriation for completing and preparing for publication other volumes of the series. The work was put in charge of Maj. J. W. Powell, previously Director of the Rocky Mountain Survey, and the Bureau of Ethnology was organized. The new Bureau continued the publication of the Contributions, and in 1880 the Director began a series of annual reports of progress to the Secretary of the Smithsonian Institution, which were published, with accompanying scientific papers, in handsomely illustrated royal octavo volumes. The printing of the volumes of both series was at first specially authorized by Congressional resolutions, but on March 2, 1881, volumes 6 to 10 of the Contributions were provided for by a single resolution.

Under authority of a joint resolution of August 5, 1886, the Director of the Bureau commenced in the following year the publication of a series of bulletins in octavo form, unbound, which was continued by authority of the concurrent resolution of July 28, 1888. The public printing act of January 28, 1895, which superseded all previous acts and resolutions relating to public printing and binding, provided for the continuance of the series of annual reports only. At that time there had been published, or were in course of publication, 8 volumes of Contributions to North American Ethnology, numbered 1–7 and 9, 24 bulletins, and 13 annual reports.

From 1895 to 1900 the Bureau issued the series of annual reports only, but on April 7 of the latter year Congress passed a concurrent resolution authorizing the commencement of a new series of bulletins in royal octavo, uniform with the annual reports. Three numbers of this series (25 to 27) have been issued. The present edition of both annual reports and bulletins is 9,682 copies, of which the Senate receives 1,500, the House 3,000, and the Bureau 3,500 (of which 500 are distributed by the Smithsonian Institution). From the remaining 1,682 are drawn the personal copies of the members of Congress, those for the Library of Congress and a few other Government libraries, and those sold by the Superintendent of Documents and distributed by him to various libraries throughout the country.

Besides the series mentioned there have been issued small editions of several miscellaneous publications intended chiefly or wholly for the use of collaborators and correspondents. These comprise three introductions to the study of aboriginal activities (one having been previously published by the Rocky Mountain Survey); a

collection of Indian gesture signs; a set of proof sheets of a bibliography of North American languages; a provisional list of the principal North American tribes, with synonyms, and two samples of style for the Dictionary of American Indians, now in preparation.

There have been issued up to the present time 19 annual reports, of which 4 are in 2 parts; 27 bulletins, of which 24 are in octavo, unbound, and 3 are in royal octavo, bound; 8 volumes of Contributions, of which one is in 2 parts; 4 introductions to the study of aboriginal activities, and 6 miscellaneous pamphlets—69 volumes and pamphlets in all.

Subject-matter of the papers.—The papers published have covered the entire range of aboriginal characters, activities, and history. Seven deal largely (3 of them almost wholly) with the classification of the tribes; almost all contain some cyclopedic material, but only 1 is devoted to it chiefly, while 18 others have a large amount of such material; 3 deal chiefly and 9 largely with history and tradition, and 3 are concerned with relations with the whites as shown through land cessions and reservations. Of those treating of aboriginal activities, 3 deal chiefly and 12 largely with social organization; 50 are devoted to arts and industries, and 20 more contain considerable material on this subject; 40 are devoted chiefly to linguistics and perhaps 35 to mythology and folklore, and a number of others contain material on both these topics. The whole constitute a record of great practical value to those dealing with the interests of the native tribes, and are of the utmost importance to the science of man.

Publications of the year.—The Nineteenth Annual Report, Bulletins 25 and 27, and a sample of style of the Dictionary of Indian Tribes (250 copies printed by the Smithsonian Institution for the use of collaborators) have been issued during the year, the Nineteenth Annual in October, 1902, Bulletin 25 in June, 1903, Bulletin 27 in January, 1903, and the pamphlet early in the same year.

Forthcoming publications.—The Twentieth, Twenty-first, and Twenty-second Annual Reports are in press, the former being almost completed, and the Twenty-third Report, containing Mrs. M. C. Stevenson's paper on the esoteric and exoteric life of the Zuñi and Dr. Frank Russell's paper on the Pima Indians, are nearly ready for transmission to the Public Printer. A paper on Haida Texts, by John R. Swanton, and a series of papers on Mexican and Mayan antiquities, history, and calendar systems, by Eduard Seler, E. Förstemann, Paul Schellhas, Carl Sapper, and E. P. Dieseldorff, is in preparation, and the following unassigned papers have been submitted: Algonquian Texts (Peoria, Miami, and Wea), by A. S. Gatschet; List of Linguistic Families of Mexico and Central America, by Cyrus Thomas.

DISTRIBUTION OF THE PUBLICATIONS.

Publications are sent to two classes of recipients: First, regularly, without special request, to working anthropologists, public libraries, scientific societies, institutions of learning, and others who are able to contribute to the work of the Bureau through publications, ethnologic specimens, or manuscript notes; second, to others in response to special requests, frequently indorsed by members of Congress.

During the year 1,380 copies each of the Nineteenth Annual Report and Bulletins 26 and 27 have been sent to regular recipients, about one-half of these going to the United States, and 3,600 miscellaneous volumes and pamphlets have been sent in response to about an equal number of special requests. More than 200 of these requests have come through Congressmen, and about 400 volumes have been sent in response.

EDITORIAL WORK.

The editorial work has been in charge of Mr. H. S. Wood, assisted during July, August, and a part of September, 1902, by Dr. Elbert J. Benton. Several sets of

proofs have also been read by the job. The work has comprised the proof reading of the Twentieth Annual Report, Bulletin 27, and Bulletin 25, and of the galleys of the Twenty-first and Twenty-second Annual Reports, the preparation of a list of abbreviations for Bulletin 25, and the reading in manuscript of the Mayan and Mexican papers already mentioned.

LIBRARY.

Although books and documents relating to ethnology were collected to a limited extent by the Geological Surveys almost from their inception, the library of the Bureau did not have a separate existence until 1882, at which time a librarian was first appointed in the United States Geological Survey, with which organization the Bureau was still domiciled. The systematic acquisition of volumes by purchase and exchange was begun at this time, though the first entry in the accessions list was not made until 1885. From then until the separation from the Survey the record shows a steady though slow growth, as allotments for purchase were small. At the time of the removal from the Survey building, in 1893, the accessioned volumes numbered about 2,500. Since that date growth has been more rapid, partly by reason of larger allotments for purchase, but chiefly through judicious exchange. The library now contains 11,863 volumes, something over 6,000 pamphlets, and several thousand numbers of periodicals, many of which should be bound and entered on the accessions list.

Only works dealing with the American Indians and such general anthropologic works as are needed for constant reference are purchased, though books and papers dealing with all branches of anthropology and with related sciences are received by exchange.

During the year there have been received 524 volumes, about 600 pamphlets, and the current numbers of more than 500 periodicals.

PROPERTY.

The property of the Bureau may be comprised in seven classes, as follows: (1) Office furniture, appliances, and supplies; (2) field outfits; (3) ethnologic manuscripts and other documents; (4) illustrations—photographs, drawings, etc.; (5) books and periodicals; (6) collections held temporarily by collaborators for use in research; (7) undistributed residue of the editions of Bureau publications.

The additions to the office and field property during the year have been few and unimportant. Numerous minor manuscripts have been added, principally in connection with the Dictionary of Indian Tribes. The illustrations material has been increased by several hundred negatives and by numerous prints and drawings. The library has continued to grow steadily through exchange and purchase.

ACCOUNTS.

When the present Chief took charge of the office Mr. F. M. Barnett was occupying the position of custodian of accounts and property. It was ascertained during the spring that vouchers were being tampered with by him, and he was promptly arrested and indicted.

A critical examination of the Bureau accounts thus became necessary, and all papers connected with disbursements were at once turned over to the disbursing officer of the Smithsonian Institution, who proceeded to give them the fullest attention. One noteworthy result of this examination was the discovery of the fact that deficiencies existed for the years 1901 and 1902 amounting to between $600 and $700. Fortunately the accounts at the close of the present year were in such shape that a sufficient balance remains to liquidate this indebtedness if Congress so desires. At the close of the year the accounting work was again placed in charge of the Bureau, and along with its other affairs was reorganized and put on a proper business footing.

Necrology.

JESSIE E. THOMAS.

On January 14, 1903, a skating accident caused the death of Miss Jessie E. Thomas, librarian of the Bureau.

Miss Thomas was born at Carbondale, Ill., October 31, 1875. She received a public school education, and studied French, German, and Spanish under private teachers; and during four years which she spent as secretary and assistant to her father, Dr. Cyrus Thomas, of the Bureau, she gained considerable knowledge of the Maya language and of the literature relating to the American Indians in general, as well as some experience in proof reading and in bibliographic work. She acquired familiarity with library methods through attendance at the Columbian University, Washington, D. C., and in May, 1900, was temporarily appointed to fill a vacancy in the staff of the Bureau library, of which Mr. F. W. Hodge was then in charge. In September the appointment was made permanent, after Miss Thomas had passed highest on an examination given by the United States Civil Service Commission to fill the position.

On Mr. Hodge's resignation in the following January she was put in full charge, and from that time until her death performed the difficult task of managing an imperfectly arranged and catalogued library with marked ability. Much of her time was taken up by the copying of the Motul Dictionary (Maya-Spanish, Spanish-Maya) from the late Doctor Brinton's collection, and in addition to her other duties she gave considerable attention to bibliographlic studies intended to lessen the labors of students of anthropology.

Her extreme carefulness and methodical habits are well illustrated by the perfect order in which all her work was left, and her staunch character, her modest demeanor and lovable disposition were highly appreciated by her associates.

JOHN WESLEY POWELL.

John Wesley Powell, founder and director of the Bureau of American Ethnology, was born March 24, 1834, at Mount Morris, N. Y. He died September 23, 1902, at his summer home in Haven, Me., and was buried with the honors due a soldier in Arlington National Cemetery.

His boyhood was spent largely in the town of Jackson, Ohio, where his mind was first directed toward the study of nature by James Crookham, an eccentric but able teacher of the village youth. He was a student for brief periods in Jacksonville and Oberlin colleges, and, taking up natural-history studies, traversed many sections of the Middle West and South, observing, studying, and collecting. It was thus, no doubt, that he acquired a decided bent for exploration, but it was probably his experience as an officer in the civil war that developed the masterly qualities which made him a leader among men and an organizer in the realm of science.

At the close of the war, declining political preferment, he resumed his scientific studies and engaged in teaching and in lecturing on geology. During his connection with Wesleyan University and the Illinois State Normal University he conducted classes in the field, and thus became more and more fully a devotee of research. In 1867 he found his way to the Far West, where later he reached the climax of his career as an explorer in his memorable voyage down the Grand Canyon of the Colorado. This expedition brought into play his splendid courage and commanding abilities, and the story of his adventures is fraught with deep romantic interest. On these voyages of exploration contact with the native tribes gave him an interest in ethnology, and thenceforth for many years his energies were divided almost equally between the sciences of geology and anthropology.

Major Powell's mind was so broadened and strengthened by the varied experiences

of his early career that when he was called upon to enter the service of the nation as explorer, geologist, geographer, and ethnologist he naturally assumed the rôle of organizer. He gathered about him the best available men in the various departments of science, assigning them to the fields for which their abilities particularly fitted them; but at all times he was the master spirit, compassing with clear vision the widest horizon, and easily pointing the way to even the ablest. His vigorous methods were an inspiration and his large-mindedness and generosity made a deep impression on scores of students, who recognized the potent influence exerted by the master.

As Director of the Geological Survey Major Powell originated and conducted many enterprises of importance to science and to public welfare, but he was finally forced by failing health to turn his back upon all branches of the public service save that relating to the Indian tribes, and in 1893 he resigned the directorship of the Geological Survey to devote the remainder of his life to the science of man, and as Director of the Bureau of American Ethnology achieved results that establish his claim to lasting renown. The Bureau of American Ethnology is peculiarly his own, the lines of research initiated by him being in the main those that must be followed as long as the Bureau lasts, and in fact as long as the human race remains a subject for study. Although the investigations made and directed by Powell related almost exclusively to the American race, the results are so broad as to apply to all mankind. It was a fortunate circumstance that his energies were directed to a field little encumbered by the forms, methods, and determinations of earlier students, since it enabled him to conduct his investigations on new lines and thus to raise the science to a higher plane.

The great series of volumes published by the Bureau, more completely Powell's own than the world can ever know, are a splendid monument to his memory, a monument that will lose none of its impressiveness as the years and generations pass, and when, a little later, the race of red men and their unique culture are but shadows on the face of the world, and other primitive peoples have likewise passed forever out of view, this monument that Powell has reared will stand, not only for himself but for the nation among the most important contributions to human history ever made by an individual, an institution, or a State. The world of the future, viewing Powell's career, will thank the guiding star that led the farmer boy to become a teacher, the teacher a soldier, the soldier an explorer, the explorer a geologist, and the geologist a historian of a vanishing race.

Respectfully submitted.

W. H. Holmes, *Chief of Bureau.*

Mr. S. P. Langley,
Secretary of the Smithsonian Institution.

Appendix III.

REPORT ON THE OPERATIONS OF THE INTERNATIONAL EXCHANGE SERVICE.

Sir: I have the honor to submit the following report of the operations of the International Exchange Service during the year ending June 30, 1903.

The work required of this branch of the Smithsonian Institution is more essentially of a business nature than that of any of its dependencies. The duties of the Exchange Service consist chiefly of transporting publications from Washington to all foreign lands, however remote, and of receiving publications from other countries, recording, and forwarding them by registered mail to their respective addresses in the United States.

The requirements of the service necessitate the handling of many packages, a large number of which consist of heavy boxes. This fact renders it necessary that the work should be conducted on the ground floor, for which reason the south basement of the Institution was remodeled ten years ago for the express use of the Exchange Service and the five rooms thus provided have since been applied to its uses. These rooms have been furnished with assorting tables, bins, record filing cases, and such other office appliances as are necessary for the use of clerks and other assistants.

Although several delays have occurred in the delivery of parcels to addresses in other countries, none of them has been due to negligence on the part of the Institution. In some instances delay was due to natural causes, and hence was unavoidable; but in the greater number of instances the delay in delivery was by reason of the fact that insufficient means are provided in some countries for conducting their respective exchange bureaus in a manner to insure prompt delivery of parcels forwarded in their care.

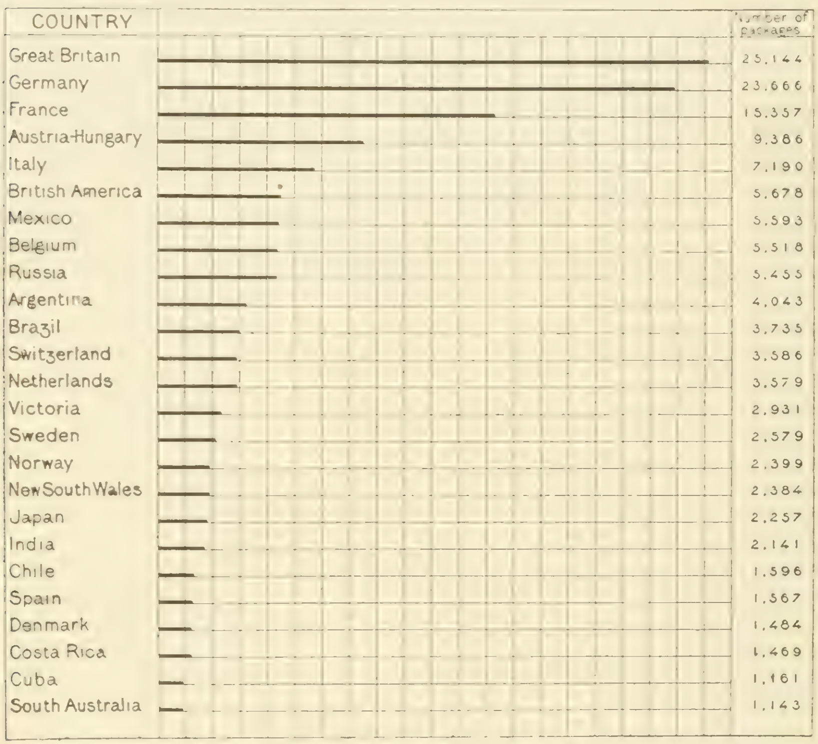
Fig. 1.—Diagram illustrating the height of packing boxes, resting with their largest surfaces one upon another, which were used in forwarding exchanges from the United States to foreign countries during the year 1903 as compared with the height of the Washington Monument. Height of boxes, 3,858 feet; height of Monument, 555 feet.

So far as reported, in only one instance during the year has any damage occurred to exchanges in transit, and even in this case it is believed that the injury was only slight. In January, 1903, the steamship *La Savoie*, of the Compagnie Générale Transatlantique, while making a voyage from New York to Havre, shipped water during a gale, and a consignment of 13 cases for French correspondents becoming wet a part of the contents was slightly damaged. It may be regarded as quite remarkable that only one accident of this character should have occurred, although several hundred shipments were made during the year.

In the report on the International Exchange Service for the year 1901 reference was made to the loss of two cases of exchanges by fire and water in the hold of the steamship *Castano* while loading at her pier in Brooklyn, preparatory to sailing for Australian ports. This loss has now been adjusted, and the contributors of the packages will soon be paid the approximate value of their respective publications.

No better proof can be desired of the appreciation of the facilities afforded the public by the International Exchange Service than the constant increase in the number of transmissions by old patrons of the service as well as the growing use to which the service is put by taking advantage of its privileges for the first time.

In order to appreciate the increase in the work of the year over that of the preced-



Each Column Represents 1,250 packages.

Fig. 2.—Chart representing the relative number of packages exchanged between the United States and other countries during the fiscal year ending June 30, 1903.

ing twelve months, it should be observed that, including all classes of exchanges, 150,217 packages, weighing 559,718 pounds, were handled in 1902–3, as against 125,796 packages, weighing 396,418 pounds, during the year 1901–2, an increase of 19 per cent and 41 per cent, respectively. The average weight of all packages transmitted during 1901–2 was 3 pounds, while the average per package during 1902–3 was nearly 4 pounds.

The total weight of exchange packages of domestic origin received during the year for transmission abroad aggregated 419,191 pounds, while the weight of exchanges from abroad was 140,527 pounds, or 75 per cent and 25 per cent, respectively. These figures apparently do not do justice to foreign contributors, especially those in remote or thinly populated sections, since, being deprived of the advantages of accessible

exchange bureaus, they are compelled to forward their reciprocal contributions to correspondents in the United States by post.

The names of new correspondents in every part of the world are constantly being added to the exchange list, so that they now reach a total of 44,012, subdivided as follows: Foreign institutions, 13,121; foreign individuals, 21,332; domestic institutions, 3,319; and domestic individuals, 6,240. Details by countries will be found in a subjoined table.

These correspondents should not be considered as participating in an exchange with the Smithsonian Institution itself, but are the beneficiaries of the facilities of the Exchange Service at home and abroad.

In 1897 a list of institutions in other countries, then numbering nearly 9,500, was printed for the use of the United States Exchange Service and similar bureaus abroad, and has been found to be of great use in facilitating their operations. During the succeeding six years, however, so many new names have been added that it has been found necessary to revise the list and to publish a new edition, the expense of which has been provided from the private funds of the Institution.

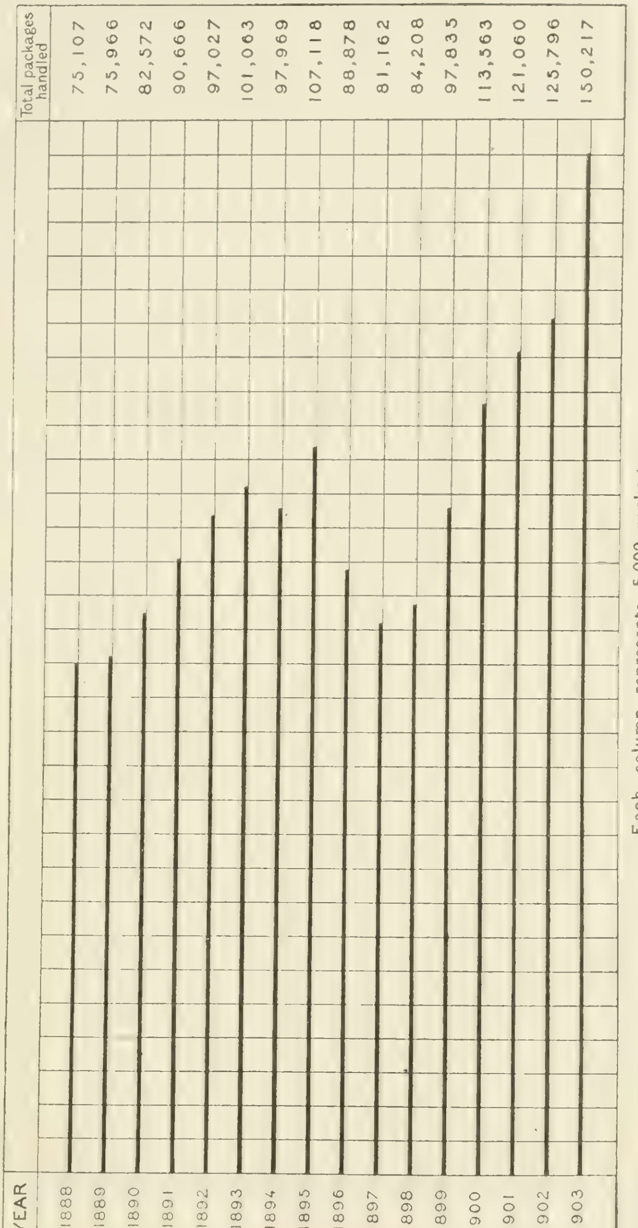


Fig. 3.—Chart showing the number of packages transmitted through the International Exchange Service each year from 1888 to 1903, inclusive.

The appropriation made by Congress for the International Exchanges during the year 1902–3 was $26,000, being the same amount as was appropriated for the fiscal year immediately preceding. Owing to the simplification of the office work, how-

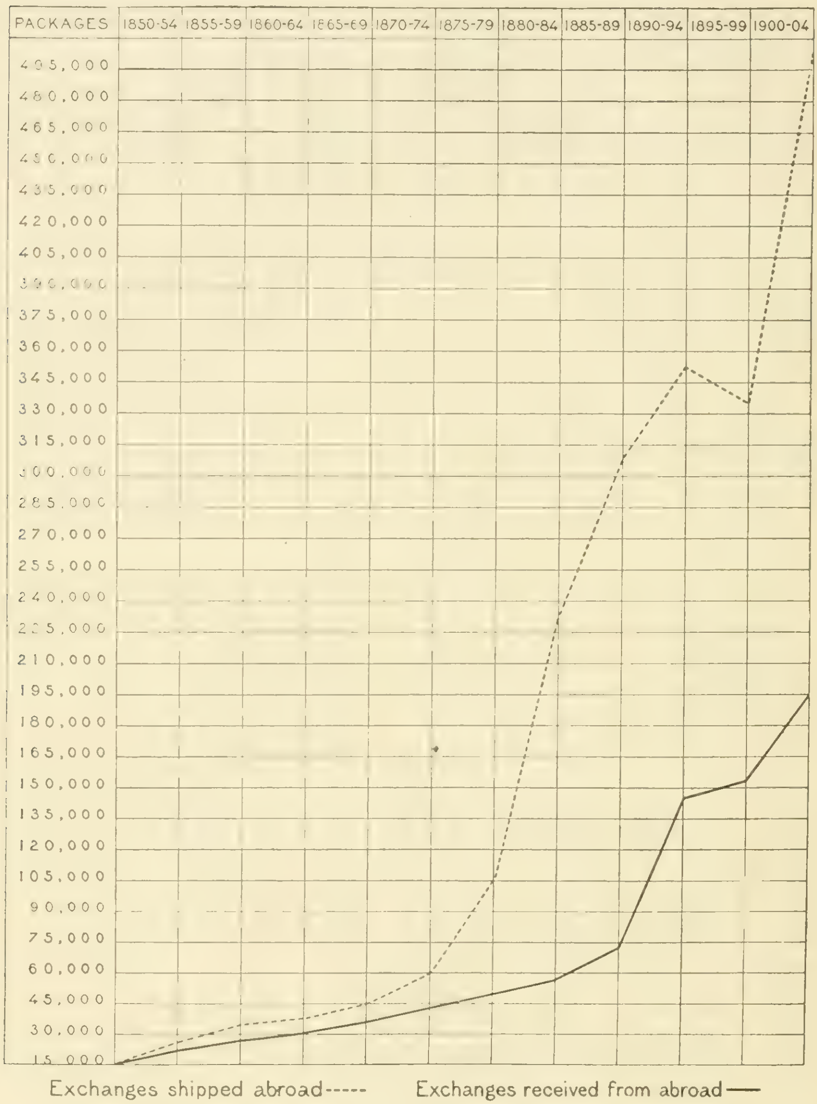


FIG. 4.—Chart representing the increase of exchange transmissions abroad from 1850 to 1904, and also of packages received from other countries for distribution in the United States during the same period. Transmissions for 1904 are estimated on the basis of the average increase during the years 1900 to 1903.

ever, it has been possible to reduce the number of employees and consequently the expenditure for services, thus enabling the Institution to meet the additional expense of the increased service without a deficit.

Tabular statement of the work of the International Exchange Service during the fiscal year 1902–1903.

Date.	Number of packages handled.	Weight of packages handled.	Number of correspondents June 30, 1902. Foreign societies.	Domestic societies.	Foreign individuals.	Domestic individuals.	Packages sent to domestic addresses.	Cases shipped abroad.
1902.								
July	10,423	57,451						
August	10,963	37,684						
September	15,741	46,822						
October	9,175	23,703						
November	12,039	57,435						
December	14,760	54,473						
1903.								
January	15,153	45,971						
February	12,126	41,216						
March	11,959	59,318						
April	17,065	46,662						
May	12,852	48,197						
June	7,961	40,783						
Total	150,217	559,718	13,121	3,319	21,332	6,240	33,980	2,461
Increase over 1901–1902	24,421	163,300	1,361	137	3,631	683	19	614

The following table shows the number of packages of exchanges handled and the increase in the number of correspondents each year from 1896 to 1903:

	1896–97.	1897–98.	1898–99.	1899–1900.	1900–1901.	1901–1902.	1902–1903.
Number of packages received	81,162	84,208	97,835	113,563	121,060	125,796	150,217
Weight of packages received, pounds	247,444	301,472	317,883	409,991	414,277	396,418	559,718
Correspondents:							
Foreign societies	9,414	10,165	10,322	10,845	11,295	11,760	13,121
Foreign individuals	12,013	12,378	13,378	15,385	16,261	17,701	21,332
Domestic societies	2,445	2,533	2,596	2,721	2,996	3,182	3,319
Domestic individuals	4,136	4,382	4,673	5,000	5,153	5,557	6,240
Packages to domestic addresses	23,619	21,057	30,645	28,625	31,367	33,961	33,980
Cases shipped abroad	1,300	1,330	1,500	1,768	1,757	1,847	2,461

CORRESPONDENTS.

The record of exchange correspondents at the close of the year contained 44,012 addresses, being an increase of 5,812 over those of the preceding year. The following table gives the number of correspondents in each country and also serves to illustrate the scope of the service:

Number of correspondents of the International Exchange Service in each country on June 30, 1903.

Country.	Correspondents. Libraries.	Individuals.	Total.
AFRICA.			
Algeria	28	37	65
Angola	1	....	1
Azores	6	14	20
Beira	....	1	1
British Central Africa	....	2	2
British East Africa	....	1	1
Canary Islands	1	....	1
Cape Colony	53	96	149
Cape Verde Islands	....	5	5
Egypt	38	65	103
French Kongo	....	1	1
Gambia	....	2	2
German East Africa	3	....	3
Gold Coast	1	3	4
Kongo	....	5	5
Lagos	2	3	5
Liberia	2	9	11
Lourenço Marquez	....	2	2
Madagascar	5	8	13
Madeira	3	4	7
Mauritius	14	10	24
Morocco	....	10	10
Mozambique	....	1	1
Natal	19	23	42
Orange River Colony	....	2	2
Reunion	....	2	2
Rhodesia	1	5	6
St. Helena	3	2	5
Senegal	1	5	6
Sierra Leone	2	3	5
Sudan	....	1	1
Transvaal	27	22	49
Tunis	9	8	17
Zanzibar	2	5	7
AMERICA (NORTH).			
Canada	304	543	847
Central America:			
British Honduras	5	12	17
Costa Rica	25	41	66
Guatemala	42	67	109
Honduras	12	36	48
Nicaragua	18	42	60
Salvador	17	11	28

Country.	Correspondents. Libraries.	Individuals.	Total.
AMERICA (NORTH)—ctd.			
Greenland	2	....	2
Mexico	165	203	368
Newfoundland	12	18	30
St. Pierre, Miquelon	2	2	4
United States	3,319	6,240	9,559
West Indies:			
Anguilla	....	1	1
Antigua	6	5	11
Bahamas	4	11	15
Barbados	10	21	31
Bermuda	6	21	27
Buen Ayre	....	1	1
Cuba	59	124	183
Curaçao	2	4	6
Dominica	2	7	9
Grenada	3	4	7
Guadeloupe	2	5	7
Haiti	38	16	54
Jamaica	19	43	62
Martinique	....	3	3
Montserrat	....	2	2
Nevis	....	1	1
Porto Rico	4	34	38
St. Bartholomew	....	2	2
St. Christopher	2	6	8
St. Croix	1	4	5
St. Eustatius	....	1	1
St. Lucia	2	4	6
St. Martin	....	2	2
St. Thomas	3	5	8
St. Vincent	1	2	3
Santo Domingo	3	11	14
Tobago	....	2	2
Trinidad	15	14	29
Turks Islands	3	4	7
AMERICA (SOUTH).			
Argentina	155	152	307
Bolivia	22	12	34
Brazil	143	154	297
British Guiana	16	12	28
Chile	83	100	183
Colombia	36	60	96
Dutch Guiana	5	5	10

Number of correspondents of the International Exchange Service in each country on June 30, 1903—Continued.

Country.	Correspondents. Libraries.	Individuals.	Total.	Country.	Correspondents. Libraries.	Individuals.	Total.
AMERICA (SOUTH)—ctd.				AUSTRALASIA—continued.			
Ecuador	15	22	37	Tasmania	21	24	45
Falkland Islands		6	6	Victoria	108	159	267
French Guiana	1	2	3	Western Australia	25	33	58
Paraguay	20	9	29	EUROPE.			
Peru	41	66	107	Austria-Hungary	787	1,190	1,977
Uruguay	45	33	78	Belgium	352	470	822
Venezuela	32	44	76	Bulgaria	13	13	26
ASIA.				Denmark	122	202	324
Arabia		7	7	France	1,785	2,369	4,154
British Burma	10	8	18	Germany	2,461	4,050	6,511
Ceylon	24	14	38	Gibraltar	1	3	4
China	49	107	156	Great Britain	2,141	5,075	7,216
Cyprus		4	4	Greece	39	48	87
Formosa	1	3	4	Iceland	17	13	30
French India	1	1	2	Italy	846	1,013	1,859
Hongkong	10	21	31	Luxemburg	11	5	16
India	238	230	468	Malta	11	11	22
Indo-China	7	8	15	Montenegro	1	1	2
Japan	162	393	555	Netherlands	226	324	550
Korea	2	11	13	Norway	140	170	310
Macao	1	1	2	Portugal	109	82	191
Malaysia:				Roumania	40	69	109
Borneo		1	1	Russia	531	895	1,426
British New Guinea		1	1	Servia	21	15	36
British North Borneo		1	1	Spain	182	225	407
Celebes		3	3	Sweden	196	375	571
Java	22	32	54	Switzerland	363	676	1,039
New Guinea		1	1	Turkey	39	85	124
Philippine Islands	11	20	31	POLYNESIA.			
Sarawak	1		1	Fiji Islands	1	3	4
Sumatra	1	3	4	German New Guinea		1	1
Persia	3	8	11	Hawaiian Islands	25	72	97
Portuguese India	1		1	Marshall Islands		1	1
Siam	7	21	28	New Caledonia		2	2
Straits Settlements	13	15	28	New Hebrides	1		1
AUSTRALASIA.				Samoa		5	5
				Tahiti		3	3
New South Wales	82	145	227	Tonga		2	2
New Zealand	88	121	209				
Queensland	39	55	94	International	37		73
South Australia	45	71	116	Total	16,440	27,572	44,012

EXCHANGE OF GOVERNMENT DOCUMENTS.

The following table exhibits the incoming and outgoing exchanges for the various branches of the United States Government during the year.

By comparison with the last report it will be observed that there was an increase during the year 1902–3 of 1,236 packages (11 per cent) received from abroad for United States institutions, while 21,110 (40 per cent) more packages were sent by the Government to addresses in other countries than during the preceding year.

Statement of Government exchanges during the year 1902–3.

Name of Bureau.	Packages.	
	Received for.	Sent by.
American Historical Association	13	16
Anthracite Coal Strike Commission	....	38
Astrophysical Observatory	8	....
Auditor for the State and other Departments	....	676
Bureau of American Ethnology	241	1,908
Bureau of the American Republics	88	....
Bureau of Education	122	....
Bureau of Insular Affairs	....	7
Bureau of the Mint	1	47
Bureau of Navigation, Navy	10	....
Bureau of Navigation, Treasury	....	210
Bureau of Ordnance, Navy	1	....
Bureau of Public Health and Marine-Hospital Service	11	1,786
Bureau of Statistics	87	5,664
Bureau of Steam Engineering	2	....
Census Office	55	5,595
Civil Service Commission	13	23
Coast and Geodetic Survey	169	1,883
Commissary-General, United States Army	....	1
Commissioner of Internal Revenue	....	12
Commissioners of the District of Columbia	3	32
Comptroller of the Currency	11	187
Department of Agriculture	465	8,181
Department of the Interior	25	910
Department of Labor	71	52
Department of State	42	....

Name of Bureau.	Packages.	
	Received for.	Sent by.
Entomological Commission	2	....
Engineer School of Application	1	....
Fish Commission	104	798
General Land Office	8	7
Geological Survey	586	6,481
Hydrographic Office	94	....
Interstate Commerce Commission	20	320
Library of Congress	5,800	21,983
Life-Saving Service	4	57
Light-House Board	2	183
National Academy of Sciences	113	508
National Bureau of Standards	1	....
National Museum	461	3,672
National Zoological Park	2	....
Nautical Almanac Office	35	371
Naval Observatory	172	1,041
Navy Department	24	....
Office of the Chief of Engineers	33	6
Office of Indian Affairs	8	....
Ordnance Office, War Department	2	....
Patent Office	266	1,823
President of the United States	1	....
Record and Pension Office	....	17
Register of the Treasury	....	3
Smithsonian Institution	2,931	7,186
Superintendent of Documents	5	4
Supervising Architect's Office	....	1
Surgeon-General's Office	175	297
Treasury Department	11	9
War Department	60	....
Weather Bureau	167	1,986
Total	12,526	73,981

RELATIVE INTERCHANGE OF PUBLICATIONS BETWEEN THE UNITED STATES AND OTHER COUNTRIES.

Following is a comparative statement of exchange transmissions by packages between the United States and other countries during the years 1902 and 1903:

Comparative statement of packages received for transmission through the International Exchange Service during the fiscal years ending June 30, 1902, and June 30, 1903.

Country.	1902. Packages.		1903. Packages.	
	For—	From—	For—	From—
Algeria	108	106	176	70
Angola	....	....	5	....
Antigua	17	....	51	....
Arabia	10	....	26	....
Argentina	2,426	787	2,535	1,508

Comparative statement of packages received for transmission through the International Exchange Service, etc.—Continued.

Country.	1902. Packages.		1903. Packages.	
	For—	From—	For—	From—
Austria-Hungary	4,480	1,843	5,667	3,719
Azores	10	....	34	....
Bahamas	12	....	12	....
Barbados	23	....	95	....
Belgium	2,322	2,072	2,728	2,790
Bermudas	17	....	65	....
Bolivia	315	11	125	14
Borneo	7	....	7	....
Brazil	1,522	1,878	2,305	1,430
British America	3,291	952	3,398	2,280
British Burma	6	....	1	....
British Guiana	71	....	114	....
British Honduras	8	....	52	....
British New Guinea	2	....	....	....
Bulgaria	80	140	133	....
Burma	....	....	3	....
Canary Islands	5	....	23	....
Celebes	1	....	1	....
Cape Colony	279	1	873	....
Ceylon	53	1	112	1
Chile	1,120	3	1,520	76
China	296	155	546	77
Colombia	691	....	733	....
Costa Rica	773	579	1,129	340
Cuba	209	37	565	596
Curaçao	5	....	27	....
Cyprus	5	....	9	....
Denmark	1,052	562	1,319	165
Dominica	19	....	12	....
Dutch Guiana	12	2	16	....
Ecuador	116	....	646	6
Egypt	173	....	286	....
Falkland Islands	3	....	12	....
Fiji Islands	2	....	3	....
Formosa	5	....	6	....
France	8,077	3,301	10,670	4,687
French Cochin China	4	....	7	...
German East Africa	....	....	8	....
Germany	14,057	6,622	17,581	6,085
Gibraltar	3	....	20	....
Gold Coast	....	....	7	....
Goree Dakar	3	....	22	....
Grenada	6	....	13	....
Great Britain and Ireland	12,790	7,122	18,038	7,106
Greece	707	40	683	....
Greenland	6	....	[illegible]	....
Guadeloupe	3	....	13	....
Guatemala	153	....	233	....
Guinea	1	....	....	....
Haiti	515	....	503	....
Hawaiian Islands	54	1	114	....
Honduras	59	119	142	11
Hongkong	80	....	127	....

Comparative statement of packages received for transmission through the International Exchange Service, etc.—Continued.

Country.	1902. Packages.		1903. Packages.	
	For—	From—	For—	From—
Iceland	41	....	55	4
India	1,451	202	1,815	326
Italy	4,423	2,541	5,795	1,395
Jamaica	94	....	246	....
Japan	1,497	21	2,245	12
Java	170	125	229	81
Kongo Free State	....	....	4	....
Korea	52	....	61	....
Lagos	1	....	3	....
Liberia	45	....	66	....
Lourenço Marquez	4	....	13	....
Luxemburg	86	26	95	....
Madagascar	6	....	38	....
Madeira	9	....	18	....
Malta	30	....	67	....
Martinique	3	....	4	....
Mauritius	56	....	76	....
Mexico	1,852	5,195	2,127	3,466
Montenegro	1	....	....	....
Montserrat	....	....	....	....
Morocco	6	....	13	....
Natal	54	2	157	30
Netherlands	1,802	700	2,479	1,100
Newfoundland	32	....	45	....
New South Wales	1,956	614	2,021	363
New Zealand	809	13	871	6
Nicaragua	81	....	138	....
Norway	1,238	57	1,459	940
Orange River Colony	....	....	5	....
Paraguay	64	251	98	47
Persia	33	....	59	....
Peru	699	1	752	1
Philippine Islands	45	5	56	....
Porto Rico	12	....	21	....
Portugal	913	317	947	38
Queensland	815	2	900	3
Reunion	8	....	16	....
Rhodesia	....	....	36	....
Roumania	154	110	261	59
Russia	3,619	1,758	4,606	849
St. Croix	5	....	5	....
St. Helena	11	....	29	....
St. Kitts	2	....	9	....
St. Martin	3	....	12	....
St. Pierre and Miquelon	1	....	2	....
St. Thomas	7	....	14	....
St. Vincent	1	....	4	....
Samoa	11	....	17	....
Samos	....	....	6	....
San Salvador	107	3	134	....
Santa Lucia	1	....	19	....
Santo Domingo	10	....	33	....

Comparative statement of packages received for transmission through the International Exchange Service, etc.—Continued.

Country.	1902. Packages.		1903. Packages.	
	For—	From—	For—	From—
Servia	51	....	71	....
Siam	39	....	84	....
Sierra Leone	3	....	13	....
Society Islands	3	....	12	....
South Australia	1,055	203	1,143	....
Spain	1,194	1	1,525	42
Straits Settlements	54	18	109	11
Sumatra	2	....	2	....
Sweden	1,843	276	2,205	374
Switzerland	2,358	2,037	2,757	829
Syria	35	....	18	....
Tasmania	600	8	569	6
Tonga	5	....	11	....
Tonquin	....	....	1	....
Transvaal	548	....	568	11
Trinidad	59	....	109	....
Tunis	27	....	55	....
Turkey	635	....	957	....
Turks Islands	11	....	27	....
United States	33,961	82,943	33,980	107,661
Uruguay	835	32	866	80
Venezuela	659	....	654	1
Victoria	1,499	691	1,786	1,145
Western Australia	664	43	619	112
Zanzibar	5	....	17	....

Several changes in the foreign relations of the Exchange Service have occurred during the year.

Through the good offices of the Department of State arrangements were consummated with Cuba for a mutual exchange of official publications, and in December, 1902, 7 boxes were shipped to Habana to be deposited in the library of the department of state at that capital.

On December 29, 1902, a reserve set of 52 cases was forwarded to the London county council as an exchange for the municipal documents of the city of London.

Transmissions to Pretoria were interrupted at the beginning of the Transvaal war, and the cases which had accumulated during hostilities were finally dispatched on March 20, 1903, to the governor of the Transvaal Colony. Later advices indicate that this set of documents will be deposited in the state library at Pretoria.

Regular shipments will be made in future to the depositories in Habana, Pretoria, and London at the rate of about one case every two months.

In January, 1903, the Queensland government established an exchange board, with headquarters in the Parliament House, Brisbane. This board has already taken up the matter of international exchanges in a systematic manner, and satisfactory results are sure to follow.

Until further notice the Exchange Service is constrained to discourage the forwarding of parcels to the Smithsonian Institution for transmission to China except those bearing addresses in Shanghai.

Reference has frequently been made in these reports to the restrictions placed

upon exchanges forwarded to Japan for distribution. The department of foreign affairs at Tokyo, to which all consignments are sent by the Smithsonian Institution, is willing to receive only parcels designed for official institutions of the Japanese Government or for individuals connected therewith. Although frequent attempts have been made to induce the foreign office to distribute all contributions for Japanese correspondents, they have thus far been of no avail.

The United States minister to Ecuador has called the attention of the Institution to the delay and expense occasioned in transporting exchanges to Quito by mountain trail from the port of Guayaquil, and suggests that only documents of great importance be sent to Quito until the railroad which is now building from the coast shall be completed, about two years hence.

The following is a list of the Smithsonian correspondents acting as distributing agents or receiving publications for transmission to the United States, and of countries receiving regularly exchanges through the Institution:

Algeria (via France).
Angola (via Portugal).
Argentina: Museo Nacional, Buenos Ayres.
Austria: K. K. Statistische Central-Commission, Vienna.
Azores (via Portugal).
Belgium: Service Belge des Échanges Internationaux, Brussels.
Bolivia: Oficina Nacional de Inmigracion, Estadística y Propaganda Geográfica, La Paz.
Brazil: Serviço de Permutações Internacionaes, Bibliotheca Nacional, Rio de Janeiro.
British Colonies: Crown Agents for the Colonies, London.[a]
Bulgaria: Dr. Paul Leverkühn, Sofia.
Canada: Sent by mail.
Canary Islands (via Spain).
Cape Colony: Superintendent of the Stationery Department, Cape Town.
Chile: Universidad de Chile, Santiago.
China: Shipments temporarily suspended.
Colombia: Biblioteca Nacional, Bogotá.
Costa Rica: Oficina de Depósito y Canje de Publicaciones, San José.
Denmark: Kongelige Danske Videnskabernes Selskab, Copenhagen.
Dutch Guiana: Surinaamsche Koloniale Bibliotheek, Paramaribo.
Ecuador: Biblioteca Nacional, Quito.
East India: India Store Department, India Office, London.
Egypt: Société Khédiviale de Géographie, Cairo.
France: Bureau Français des Échanges Internationaux, Paris.
Friendly Islands: Sent by mail.
Germany: Dr. Felix Flügel, Äussere Halle'sche strasse No. 18, Leipzig-Gohlis.
Great Britain and Ireland: Messrs. William Wesley & Son, 28 Essex street, Strand, London.
Greece: Director of the American School of Classical Studies, Athens.
Greenland (via Denmark).
Guadeloupe (via France).
Guatemala: Instituto Nacional de Guatemala, Guatemala.
Guinea (via Portugal).
Haiti: Secrétaire d'État des Relations Extérieures, Port au Prince.
Honduras: Biblioteca Nacional, Tegucigalpa.
Hungary: Dr. Joseph von Körösy, "Redoute," Budapest.

[a] This method is employed for communicating with a large number of the British colonies with which no means is available for forwarding exchanges direct.

Iceland (via Denmark).
Italy: Ufficio degli Scambi Internazionali, Biblioteca Nazionale Vittorio Emanuele, Rome
Java (via Netherlands).
Korea (via Russia).
Liberia: Care of American Colonization Society, Washington, D. C.
Luxemburg (via Germany).
Madagascar (via France).
Madeira (via Portugal).
Mexico: Sent by mail.
Mozambique (via Portugal).
Natal: Agent-General for Natal, London.
Netherlands: Bureau Scientifique Central Néerlandais, Bibliothèque de l'Université Leyden.
New Guinea (via Netherlands).
New Hebrides: Sent by mail.
Newfoundland: Sent by mail.
New South Wales: Board for International Exchanges, Sydney.
New Zealand: Colonial Museum, Wellington.
Nicaragua: Ministerio de Relaciones Exteriores, Managua.
Norway: Kongelige Norske Frederiks Universitet, Christiania.
Paraguay: Ministerio de Relaciones Exteriores, Asuncion.
Persia (via Russia).
Peru: Seccion para el Canje de Publicaciones Internacionales, Ministerio de Fomento, Lima.
Portugal: Bibliotheca Nacional, Lisbon.
Queensland: Exchange Board, Parliament House, Brisbane.
Roumania (via Germany).
Russia: Commission Russe des Échanges Internationaux, Bibliothèque Impériale Publique, St. Petersburg.
Salvador: Museo Nacional, San Salvador.
Santo Domingo: Sent by mail.
Servia (via Germany).
Siam: Board of Foreign Missions of the Presbyterian Church, New York.
South Australia: Astronomical Observatory, Adelaide.
Spain: Oficina para el Canje de Publicaciones Oficiales, Cientificas y Literarias, Seccion de Propiedad Intelectual del Ministerio de Fomento, Madrid.
Sumatra (via Netherlands).
Syria: Board of Foreign Missions of the Presbyterian Church, New York.
Sweden: Kongliga Svenska Vetenskaps Akademien, Stockholm.
Switzerland: Service des Échanges Internationaux, Bibliothèque Fédérale Centrale, Berne.
Tasmania: Royal Society of Tasmania, Hobart.
Tunis (via France).
Turkey: American Board of Commissioners for Foreign Missions, Boston.
Uruguay: Oficina de Depósito, Reparto y Canje Internacional, Montevideo
Venezuela: Biblioteca Nacional, Caracas.
Victoria: Public Library, Museums, and National Gallery, Melbourne.
Western Australia: Victoria Public Library, Perth.
Zanzibar: Sent by mail.

The distribution of exchanges to foreign countries was made in 2,461 cases, 257 of which contained official documents for authorized depositories, and the contents of 2,204 cases consisted of Government and other publications for miscellaneous corre-

spondents. Of the latter class of exchanges, the number of cases sent to each country is given below:

Argentina	44	Natal	3
Austria	86	New South Wales	44
Barbados	1	Netherlands	52
Belgium	66	New Providence	1
Bermuda	1	New Zealand	15
Bolivia	5	Nicaragua	6
Brazil	44	Norway	30
British colonies	30	Paraguay	2
British Guiana	2	Peru	12
British Honduras	2	Polynesia	([b])
Cape Colony	12	Portugal	20
China	4	Queensland	9
Chile	20	Roumania	([c])
Colombia	11	Russia	75
Costa Rica	15	Salvador	5
Cuba	2	Santo Domingo	5
Denmark	30	Servia	([c])
Dutch Guiana	([a])	Siam	1
Ecuador	9	South Australia	20
East Indies	22	Spain	30
Egypt	6	St. Kitts	1
France and colonies	244	St. Lucia	1
Germany	364	Sweden	50
Great Britain and Ireland	426	Switzerland	60
Greece	10	Syria	([b])
Guatemala	9	Tasmania	5
Haiti	2	Transvaal	([d])
Honduras	7	Trinidad	4
Hungary	40	Turkey	7
Italy	94	Uruguay	15
Jamaica	6	Venezuela	15
Japan	65	Victoria	23
Liberia	2	Western Australia	12
Mexico	([b])		

Following is a list of foreign depositories to which sets of United States Government publications are sent under the joint resolution of Congress approved March 2, 1867. One box of current publications was forwarded to each depository on September 8, October 2, and December 17, 1902, and on February 17 and April 27, 1903:

Argentina: Library of the Foreign Office, Buenos Ayres.
Argentina: Biblioteca Pública Provincial, La Plata.
Australia: Commonwealth of Australia, Melbourne.
Austria: K. K. Statistische Central-Commission, Vienna.
Baden: Universitäts-Bibliothek, Freiburg.
Bavaria: Königliche Hof- und Staats-Bibliothek, Munich.
Belgium: Bibliothèque Royale, Brussels.
Brazil: Bibliotheca Nacional, Rio de Janeiro.

[a] Included in transmissions to Netherlands.
[b] Packages sent by mail.
[c] Included in transmissions to Germany.
[d] Included in transmissions to Great Britain.

Canada: Parliamentary Library, Ottawa.
Chile: Biblioteca del Congreso, Santiago.
Colombia: Biblioteca Nacional, Bogotá.
Costa Rica: Oficina de Depósito y Canje de Publicaciones, San José.
Cuba: Department of State, Habana.
Denmark: Kongelige Bibliotheket, Copenhagen.
England: British Museum, London.
England: School of Economics and Political Sciences, London.
France: Bibliothèque Nationale, Paris.
Germany: Deutsche Reichstags-Bibliothek, Berlin.
Greece: National Library, Athens.
Haiti: Secrétaire d'État des Relations Extérieures, Port au Prince.
Hungary: Hungarian House of Delegates, Budapest.
India: Secretary to the Government of India, Calcutta.
Ireland: National Library of Ireland, Dublin.
Italy: Biblioteca Nazionale Vittorio Emanuele, Rome.
Japan: Foreign Office, Tokyo.
Mexico: Instituto Bibliográfico, Museo Nacional, Mexico.
Netherlands: Library of the States General, The Hague.
New South Wales: Board for International Exchanges, Sydney.
New Zealand: General Assembly Library, Wellington.
Norway: Storthingets Bibliothek, Christiania.
Ontario: Legislative Library, Toronto.
Peru: Biblioteca Nacional, Lima.
Portugal: Bibliotheca Nacional, Lisbon.
Prussia: Königliche Bibliothek, Berlin.
Quebec: Legislative Library, Quebec.
Queensland: Parliamentary Library, Brisbane.
Russia: Imperial Public Library, St. Petersburg.
Saxony: Königliche Bibliothek, Dresden.
South Australia: Parliament Library, Adelaide.
Spain: Seccion de Propiedad Intelectual del Ministerio de Fomento, Madrid.
Sweden: Kongliga Biblioteket, Stockholm.
Switzerland: Bibliothèque Fédérale, Berne.
Tasmania: Parliamentary Library, Hobart.
Transvaal: State Library, Pretoria.
Turkey: Minister of Public Instruction, Constantinople.
Uruguay: Oficina de Depósito, Reparto y Canje Internacional de Publicaciones, Montevideo.
Venezuela: Biblioteca Nacional, Carácas.
Victoria: Public Library, Melbourne.
Western Australia: Victoria Public Library, Perth.
Württemberg: Königliche Bibliothek, Stuttgart.

The 50 sets of official documents provided by the joint resolution of Congress approved March 2, 1867, have all been placed in appreciative hands in other countries, as noted in the preceding list. Finding that a still further exchange with foreign governments was necessary in order to increase the collections in the Library of Congress, a joint resolution was approved March 2, 1901, providing 62 sets for distribution abroad in lieu of 50 sets as formerly, and further provision was made by this resolution for increasing the number of sets to 100 on the request of the Librarian of Congress.

The distribution of the additional sets provided for by the joint resolution of March 2, 1901, has been made through the International Exchange Service to such foreign depositories as the Librarian of Congress in his judgment has deemed expedient.

having solely in view the procurement of such publications in exchange as were especially desired by that library.

On account of lack of space in the Smithsonian building for storing the additional sets provided for by the resolution of 1901, these documents have been delivered from the Government Printing Office to the Library of Congress, and in turn are forwarded to the Smithsonian Institution from time to time for transmission abroad as negotiations are consummated. When depositories for all these additional sets shall have been arranged for, however, it is expected that the documents will be delivered directly from the Government Printing Office to the Smithsonian Institution, and that all uniform sets will then be shipped abroad at the same time and accompanied by duplicate printed lists of the contents of each case, as is now customary when shipments are made to the original 50 depositories.

The following is a list of the new depositories to which consignments have been made during the year:

British Columbia: Legislative Assembly, Victoria.

Cape Colony: Colonial Governor, Cape Town.

France: Prefecture de la Seine, Paris.

Germany: Foreign Office, Bremen.

Guatemala: Secretary of the Government, Guatemala.

Jamaica: Colonial Secretary, Kingston.

Manitoba: Provincial Library, Winnipeg.

Natal: Colonial Secretary's Office, Pietermaritzburg.

New Brunswick: Legislative Library, Fredericton.

Northwest Territories: Government Library, Regina.

Nova Scotia: Legislative Library, Halifax.

Prince Edward Island: Legislative Library, Georgetown.

Dr. Felix Flügel, Messrs. William Wesley & Son, and Dr. Joseph von Körösy continue to act as agents of the Institution in Leipzig, London, and Budapest, respectively. In each instance the interests of the Institution generally, and those of the International Exchange Service in particular, are conducted with rare ability.

To those correspondents abroad who give their personal attention and doubtless often expend private means in furthering the interests of international exchanges at large the grateful acknowledgment of the Institution should be accorded.

The appreciation of the Smithsonian Institution and its branches is due to Mr. Charles A. King, deputy collector of the port of New York, for his constant assistance in clearing assignments from abroad for the Institution. I desire to commend also the efficiency and faithfulness of the employes of the exchange service throughout the year.

Respectfully submitted.

F. W. Hodge,
Acting Curator of Exchanges.

Mr. S. P. Langley,
Secretary of the Smithsonian Institution.

July 1, 1903.

Appendix IV.

REPORT OF THE SUPERINTENDENT OF THE NATIONAL ZOOLOGICAL PARK.

Sir: I have the honor to herewith submit the following report relating to the condition and operations of the National Zoological Park for the year ending June 30, 1903:

At the close of that period the approximate value of the property belonging to the park was as follows:

Buildings for animals	$84,000
Buildings for administrative purposes	14,000
Office furniture, books, apparatus, etc	4,000
Machinery, tools, and implements	2,200
Fences and outdoor inclosures	33,000
Roadways, bridges, paths, rustic seats, etc	80,000
Nurseries	1,000
Horses	400
Animals in zoological collection	40,000

A detailed list of the animals in the collection is appended hereto. They may be classified as follows:

	Indigenous.	Foreign.	Domesticated.	Total.
Mammals	310	143	82	535
Birds	158	125	64	347
Reptiles	101	17		118
Total	569	285	146	1,000

The accessions of animals during the year have been as follows:

Presented	113
Purchased and collected	102
Lent	3
Received from Yellowstone National Park	1
Received in exchange	21
Born in National Zoological Park	87
Received from United States consul at Newcastle, New South Wales	143
Total	470

The cost for purchase, collection, and transportation of these accessions has been $4,500.

The appropriation for the general service of the park was made in the following terms:

For continuing the construction of roads, walks, bridges, water supply, sewerage and drainage; and for grading, planting, and otherwise improving the grounds; erect-

ing and repairing buildings and inclosures; care, subsistence, purchase, and transportation of animals, including salaries or compensation of all necessary employees; the purchase of necessary books and periodicals, the printing and publishing of operations, not exceeding one thousand five hundred copies, and general incidental expenses not otherwise provided for, ninety thousand dollars.

An additional appropriation was made as follows:

For the construction of an elephant house, with bathing pools and other accessories, including labor and materials and all necessary incidental expenses, ten thousand dollars; one-half of which sums for the National Zoological Park shall be paid from the revenues of the District of Columbia and the other half from the Treasury of the United States. (Sundry civil act June 28, 1902.)

In submitting estimates to Congress $20,000 was specified for the elephant house. Only half of this amount was appropriated, which was altogether inadequate for such a building as had been planned—in fact, was sufficient only to inclose the required space with the cheapest possible construction having the necessary strength.

The preparation of new plans and specifications adapted to the amount available was begun as soon as the appropriation had been made and a contract for the work was let early in September. Work under the contract was commenced promptly and pushed as rapidly as circumstances would permit. There was some unavoidable delay in securing materials, but the building was completed early in January, 1903. The contract covered building proper, outdoor bathing pool, and fence for outside yard, and amounted to $8,594. Boiler and heating pipes and some other interior fittings and guard rail around outside yard were not included in the contract, this work being done by day labor. The total cost, including architect's commission, was $10,000. About $500 also was expended from the general appropriation in necessary grading and construction of walks in the immediate vicinity.

The house is a plain, barn-like structure of brick, 35 by 65 feet inside, a space 35 feet square being provided for the elephant, a 10-foot passage reserved for attendants, and a space 20 by 35 feet for the public. The outside yard is 79 by 96 feet and includes a concrete bathing pool 20 feet in diameter and 6 feet deep. The fence is 6 feet high, constructed of steel throughout, and consists of I-beam posts, channel-beam rail, and pickets of 2¼-inch stiff, round steel 19 inches apart. Both posts and pickets are set in a heavy concrete base. A bar of 2-inch half-round iron, in which are set small pointed steel knobs, is fastened along the inner side of the rail to discourage the elephant from pushing against it. An area between the yard and pool, protected by a stockade, has been planted with shrubs and trees, which will soon shade to a considerable extent both yard and pool. The accompanying illustration shows the exterior appearance of the house and yard. The elephant was put in the house March 12, 1903.

Besides the regular cost of maintenance, several important improvements have been made during the year from the general appropriation.

Boundary fence.—The Secretary had for several years been urging upon Congress the need of replacing the wooden boundary fence, which was constructed in 1890. There was an increase of $10,000 in the general appropriation over the sum provided for the previous year, and this amount was applied to the construction of a new fence. Work was begun soon after the appropriation became available, and the fence was completed during autumn, except on a small portion of the boundary, where the grades are being changed to conform to newly constructed highways of the District of Columbia. The fence consists of Page woven-wire fencing, 72 inches wide, of extra strength, and carried on posts of heavy iron pipe set in concrete bases. Three barbed wires are used above, making the total height 90 inches. Heavy galvanized netting extends 12 inches into the ground below for security against dogs.

The amount available was not sufficient to provide suitable entrance gates, and temporary gates were made with wire fencing attached to a light frame of angle iron. The total cost of the fence was $10,000.

Elephant House and Yard in National Zoological Park.

ECHIDNA. "TASMANIAN DEVIL."

TASMANIAN "ZEBRA WOLF."

(Obtained by Dr. F. W. Goding, U. S. Consul at Newcastle, New South Wales.)

In connection with the building of the fence it became necessary to reestablish certain points on the boundary line where the grading of District highways had displaced the original marks or where the line had been altered since the official survey was made. The surveyor of the District of Columbia was accordingly employed to resurvey the boundary and prepare a new and authoritative map.

Bear yards.—Two bear yards begun at the close of the previous year have been completed. Provision has been made for a series of 10 yards, and the site for the entire series has been graded. The two central cages of the series were built and are occupied, respectively, by the Kodiak bear and the pair of polar bears. These cages are approximately 40 feet square, and each contains a bathing pool about 20 feet in diameter. The fence is 10 feet high, with an overhang inward of 2 feet 6 inches. It is constructed of vertical bars of $\frac{3}{4}$-inch stiff round steel, spaced 5 inches on centers, passing through horizontal rails of $2\frac{1}{2}$ by $\frac{3}{4}$ inch round-edged steel. Each yard is provided with a house in the rear, the front of which is of large weathered rocks laid up with wide irregular joints. Rear walls are of concrete. Each house has a grating door at front and rear and a grating across one end the entire width of the house. In winter a tight storm door is fitted into the rear opening, and the open end of the house is closed with a wooden panel. The door at the front is closed with a sliding grating, operated outside the house. There is also a grating door at the rear of the yard for the use of keepers, all attendance being from the rear. The cost, including grading, drainage, and water supply, has been $3,000. Trees have been planted about the cages, which after a few years will shade both animals and visitors. A trellis of light steel framework has been constructed over the public walk and the front part of the cages, and over this quick-growing vines are being trained, which will afford shade till the trees reach sufficient size to render such shade unnecessary.

Eagle cage.—This structure also was begun as the last fiscal year ended. It was completed early in the present year and at once occupied. The cage has proved to be very satisfactory, and it is hoped that in the near future similar structures can be built for other birds of prey, especially for the California condors, which now have to be kept in a cage of quite inadequate size.

The following alterations and additions have been made to buildings and grounds during the year:

Improvements in aquarium.—The small aquarium maintained for several years in an old work shed proved to be of so much interest to visitors that it seemed advisable to make some alterations in order to provide more satisfactory conditions for operation and exhibition. Under your instructions the lighting, which had been insufficient, was improved by putting in a continuous series of skylights on the north side and doubling the skylight area on the south side. A new exhibition tank, 12 feet long, 3 feet 10 inches high, and 5 feet deep, was constructed at the end of the corridor. A second concrete storage tank for salt water was built and an extra pump and additional piping put in, so that the entire series of tanks on one side and the new end tank can be supplied with salt water. It was also recognized that a bare background of asphalted wood did not display fishes to advantage or give any proper idea of the surroundings in which they ordinarily live. Some of the tanks have therefore been lined with rock of different kinds, while in others cement has been combined with gravel and waterworn stones to give the background the appearance of a natural bank. Fresh-water plants, marine algæ, sponges, etc., have been used as accessories in these tanks to produce, so far as possible, the appearance of natural conditions. The improvement thus made has been appreciated by the public as well as favorably commented on by persons engaged in aquarium work.

A large mirror has been installed on the roof of the aquarium and so connected that it throws sunlight at all times of day, through colored glass, into one of the tanks.

Addition to temporary bird house.—It was found to be necessary to further enlarge the temporary bird house in order to furnish winter quarters for birds from the large flying cage. An extension 50 feet long and 35 feet wide was built at the north end with a height of 20 feet. The end of this extension was made into a single cage, 20 by 35 feet, extending the full height of the building and provided with a pool, trees, etc. A considerable part of the birds from the flying cage were kept here during the winter. This addition made it possible to keep birds in a fairly comfortable manner, but, with accessions which have come in during the current year, especially from United States officers abroad, the collection has again quite outgrown the accommodations.

Repairs to antelope house.—When this house was built it was necessary, on account of insufficiency of funds, to use the cheapest materials. As a natural result some parts of the structure have already given away from decay. During the year it became necessary to put new floors in all of the large cages. The wooden floors were removed and replaced by a macadam surface on a base of stone laid in the "Telford" manner. Concrete walls were built to sustain the front of the cages and the partitions. New double partitions were also constructed, with doors sliding into them, and the outer wall was ceiled for greater warmth.

Repairs to inclosures.—Several of the inclosures for ruminant animals have required repairs during the year. The elk paddock was in such bad condition that the wire fencing had to be replaced for a distance of 100 rods, and at least an equal amount additional will have to be rebuilt very soon. A fence possessing at once the desirable qualities of lightness, strength, and durability is apparently not yet obtainable.

Work on roadways.—No new roadways have been constructed during the year, but the driveway connecting with Klingle road was rebuilt for a distance of 300 feet in order to conform to the new grade established for that road. The ford on this driveway was also paved with concrete, as the current of Rock Creek frequently eroded the natural bed at that point to such an extent as to render the crossing unsafe for carriages. Since this improvement was made there has been no further trouble of this kind. It also became necessary to remove the metaling from the roadway between Quarry road entrance and the bridge over the creek, as a considerable fill was required there to connect with the new entrance road constructed by the District at that point.

New entrance road from Kenesaw avenue.—The appropriations for the District of Columbia included the following item: "For Kenesaw avenue, entrance to Zoological Park, grading (and the Commissioners of the District of Columbia are authorized to adjust the lines of the streets at this locality so as to afford an entrance to the Zoological Park upon good and satisfactory grade, with authority to exchange with the owners of the abutting property any land now within the lines of said streets that may be necessary to accomplish said purpose: *Provided*, That no expense is incurred thereby by the United States or the District of Columbia), ten thousand dollars."

This entrance roadway has been graded throughout to a width of 50 feet. It has not as yet been otherwise improved, but will probably be graveled soon. A fill was required the entire length of the road, which extends into the park about 200 feet, and the side slope encroaches on the park the whole length. The park is now bordered on the east side from Quarry road to Klingle road by a bank of raw earth as steep as it will stand and from 15 to 40 feet high. Measures will have to be taken to protect the meadow and woodland below from the wash, also to plant the slope so as to screen it and cover it with a growth of vegetation which will hold the earth and prevent erosion.

Important accessions.—Dr. F. W. Goding, United States consul at Newcastle, New South Wales, secured for the park during the year the most important collections yet received from any one source, amounting to more than 140 specimens, among

which were a Tasmanian zebra wolf with 3 young, a Tasmanian devil, 3 echidnas, 13 kangaroos of various species, 3 phalangers, 2 flying phalangers, 4 native cats (*Dasyurus*), a black-backed jackal, a pair of emus, 30 cockatoos and paroquets, a wedge-tailed eagle, a pair of black swans, and many other birds. A number of these animals were gifts from Doctor Goding, or through him, from persons in Australia who are interested in natural history; others which were especially difficult to obtain were purchased by Doctor Goding at small cost through correspondents in remote parts of Australia and Tasmania. His wide acquaintance throughout the Australian region and knowledge of its fauna made it possible for Doctor Goding to secure a thoroughly representative collection, and acknowledgment is here given of the gratitude of the park and of its obligation to Doctor Goding for his valuable assistance. Some of the animals mentioned are shown in Plate II.

E. H. Plumacher, United States consul at Maracaibo, Venezuela, presented a monkey, a deer, a peccary, 2 agoutis, and several iguanas, parrots, and owls.

E. S. Cunningham, United States consul at Aden, Arabia, presented a fine specimen of caracal.

An officer of the Sudan government offered to the President of the United States a young lion, which was secured for the park. Dr. H. T. McLaughlin, of the American mission at Omdurman, kindly attended to the forwarding of the animal, which proved to be a fine male about 12 months old.

The President presented to the park a bay lynx and a black bear.

Victor J. Evans, of Washington, D. C., presented a fine male Arabian baboon.

Capt. John L. Young, of Young's Pier, Atlantic City, N. J., presented the aquarium with a number of interesting fishes and also assisted materially in securing other specimens.

The Yellowstone National Park, through its acting superintendent, Maj. John Pitcher, U. S. Army, furnished a fine male grizzly bear, weighing 500 pounds. *Exchanges* were made during the year with the New York Zoological Park; Lincoln Park, Chicago; the Zoological Garden at Buffalo, N. Y., and various private individuals, by means of which surplus animals were disposed of and desirable specimens obtained. *Births* increased somewhat in number over the previous year, and it is of interest to note that the beavers have again bred, this time producing three young.

Purchases included a young female lion obtained for the park by the United States consul at Aden, Arabia, a specimen of the Oregon cougar, 2 fishers, a female moose as a mate for the male already in the collection, 4 Cuban flamingos, also a male llama and several birds which did not arrive until after the close of the fiscal year.

The young brown bear obtained on the mainland of Alaska, opposite Kodiak Island, in May, 1901, made a very satisfactory growth and weighed, in June of this year, 450 pounds. Its weight when captured was 18 pounds. This bear is probably of the kind recently described as *Ursus gyas*.

Losses of animals.—The most important were 5 American bison, 3 of which died from gastro-enteritis, 1 from abscess of the stomach, and 1 from pyæmia; 2 woodland caribou, 2 prong-horn antelopes, also 15 monkeys, the loss of which must be charged mainly to lack of proper housing.

Autopsies on a considerable proportion of the animals which died were made by the Bureau of Animal Industry of the United States Agricultural Department, and facts of interest were learned as well as information secured which will be of service to the park in the future.

One draft horse and one saddle horse were condemned during the year as unfit for use and were sold at public auction.

The urgent need of a house for small mammals was brought to the attention of Congress, and, while no separate appropriation was made for this purpose, it is hoped that from the slightly increased general appropriation for the year 1904 a sufficient

amount can be reserved to erect at least a part of the building. Plans for the house are already well under way.

It would be of the greatest advantage to the park if immediate provision could be made for its most vital needs. A central heating plant is one of the indispensable features of a permanent equipment and must be put in ultimately. The establishment of such a plant will result not only in direct and immediate economy through reducing the amount of fuel and the number of firemen required, but it will also save the expense of providing each building erected with a separate heating plant, and will remove from all the public exhibition houses the dirt, smoke, and other inconveniences which necessarily attend the operation of a heating plant in the building.

Need of a suitable public comfort house equipped for ladies and children and with provision for a restaurant has before been mentioned and is again urged. The present insufficient arrangements are becoming each year more unsatisfactory and objectionable. It may be mentioned that accommodations of this kind are among the most important features in all of the leading zoological gardens.

Attention is again called to the great desirability of providing permanent buildings for animals sufficient to keep pace with the growth of the collections, so that there may be no further necessity for putting up cheap temporary structures, which are never satisfactory and entail a greater final cost than would result were permanent houses provided at the outset.

Animals in National Zoological Park, June 30, 1903.

Name.	Number.	Name.	Number.
MAMMALS.		MAMMALS—continued.	
North American species.		*North American species*—Continued.	
American bison (*Bison americanus*)	4	Cross fox (*Vulpes fulvus*)	1
Prong-horn antelope (*Antilocapra americana*)	2	Arctic fox (*Vulpes lagopus*)	12
Virginia deer (*Odocoileus virginianus*)	12	Swift fox (*Vulpes velox*)	6
Columbia black-tailed deer (*Odocoileus columbianus*)	1	Gray fox (*Urocyon cinereoargenteus*)	3
Mule deer (*Odocoileus hemionus*)	10	North American otter (*Lutra hudsonica*)	2
Cuban deer (*Odocoileus* sp.)	1	Fisher (*Mustela pennantii*)	2
American elk (*Cervus canadensis*)	33	American badger (*Taxidea taxus*)	4
Newfoundland caribou (*Rangifer terrænovæ*)	1	Kinkajou (*Totos caudivolvulus*)	2
Moose (*Alces americanus*)	2	American civet cat (*Bassariscus astutus*)	1
Collared peccary (*Tayassu angulatum*)	1	Raccoon (*Procyon lotor*)	22
Cougar (*Felis concolor*)	2	Black bear (*Ursus americanus*)	6
Oregon cougar (*Felis concolor oregonensis*)	1	Cinnamon bear (*Ursus americanus*)	2
Ocelot (*Felis pardalis*)	9	Grizzly bear (*Ursus horribilus*)	4
Yaguarundi (*Felis yaguarundi*)	2	Yakutat bear (*Ursus dalli*)	1
Eyra (*Felis eyra*)	1	Kodiak bear (*Ursus middendorffi*)	1
Bay lynx (*Lynx rufus*)	1	Polar bear (*Thalarctos maritimus*)	2
Spotted lynx (*Lynx rufus maculatus*)	2	California sea lion (*Zalophus californianus*)	1
Florida lynx (*Lynx rufus floridanus*)	2	Steller's sea lion (*Eumetopias stelleri*)	1
Canada lynx (*Lynx canadensis*)	1	Harbor seal (*Phoca vitulina*)	3
Gray wolf (*Canis griseus*)	5	Common pocket gopher (*Geomys bursarius*)	2
Black wolf (*Canis griseus*)	3	California pocket gopher (*Thomomys bottæ*)	2
Coyote (*Canis latrans*)	6	Mountain pack-rat (*Neotoma cinerea*)	3
Coyote (*Canis frustror*)	4	American beaver (*Castor canadensis*)	11
Red fox (*Vulpes fulvus*)	2	Hutia-conga (*Capromys pilorides*)	9
		Southern fox squirrel (*Sciurus niger*)	5

Animals in National Zoological Park, June 30, 1903—Continued.

Name.	Number.
MAMMALS—continued.	
North American species—Continued.	
Western fox squirrel (*Sciurus ludovicianus*)	16
Gray squirrel (*Sciurus carolinensis*)	34
Black squirrel (*Sciurus carolinensis*)	9
Mountain chipmunk (*Tamias speciosus*)	18
Beechey's ground squirrel (*Spermophilus grammurus beecheyi*)	1
Antelope chipmunk (*Spermophilus leucurus*)	2
Mexican ground squirrel (*Spermophilus mexicanus*)	1
Northern varying hare (*Lepus americanus*)	9
Peba armadillo (*Tatu novemcinctum*)	4
Opossum (*Didelphys marsupialis*)	2
Domesticated and foreign species.	
Bonnet monkey (*Macacus sinicus*)	1
Macaque monkey (*Macacus cynomolgus*)	10
Pig-tailed monkey (*Macacus nemestrinus*)	3
Japanese monkey (*Macacus speciosus*)	1
Black ape (*Cynopithecus niger*)	4
Arabian baboon (*Papio hamadryas*)	2
Spider monkey (*Ateles* sp.)	1
Capuchin (*Cebus capucinus*)	2
Ruffed lemur (*Lemur varius*)	2
Lion (*Felis leo*)	7
Tiger (*Felis tigris*)	2
Leopard (*Felis pardalis*)	2
Caracal (*Lynx caracal*)	1
Spotted hyena (*Hyæna crocuta*)	1
Striped hyena (*Hyæna striata*)	2
Wolf hound	2
St. Bernard dog	1
Pointer	1
Bedlington terrier	1
Smooth-coated fox terrier	3
Wire-haired fox terrier	1
Dingo (*Canis dingo*)	2
Black-backed jackal (*Canis mesomelas*)	1
Palm civet (*Paradoxurus fasciatus*)	1
Mongoose (*Herpestes mungo*)	1
Tayra (*Galictis barbara*)	1
Red coatimundi (*Nasua rufa*)	1
Crab-eating raccoon (*Procyon cancrivora*)	2
Japanese bear (*Ursus japonicus*)	1
Sun bear (*Ursus malayanus*)	1
Sloth bear (*Melursus ursinus*)	2
European hedgehog (*Erinaceus europæus*)	1
Wild boar (*Sus scrofa*)	2

Name.	Number.
MAMMALS—continued.	
Domesticated and foreign species—Con.	
Solid-hoofed pig (*Sus scrofa*)	1
Zebu (*Bos indicus*)	5
Carabao (*Bos bubalus*)	1
Yak (*Poëphagus grunniens*)	2
Barbary sheep (*Ovis tragelaphus*)	5
Common goat (*Capra hircus*)	15
Angora goat (*Capra hircus*)	7
Nilgai (*Boselaphus tragocamelus*)	4
Indian antelope (*Antilope cervicapra*)	2
Sambur deer (*Cervus aristotelis*)	2
Philippine deer (*Cervus philippinus*)	1
Axis deer (*Cervus axis*)	1
Red deer (*Cervus elaphus*)	1
Mexican deer (*Odocoileus mexicanus*)	1
Venezuelan deer (*Cariacus* sp.)	1
Fallow deer (*Dama vulgaris*)	5
Common camel (*Camelus dromedarius*)	2
Bactrian camel (*Camelus bactrianus*)	1
Llama (*Auchenia glama*)	3
South American tapir (*Tapirus americanus*)	3
Donkey (*Equus asinus*)	1
Indian elephant (*Elephas indicus*)	1
Mexican agouti (*Dasyprocta mexicana*)	1
Hairy-rumped agouti (*Dasyprocta prymnolopha*)	2
Azara's agouti (*Dasyprocta azaræ*)	2
Acouchy (*Dasyprocta acouchy*)	4
Golden agouti (*Dasyprocta aguti*)	1
Guinea pig (*Cavia porcellus*)	17
Albino rat (*Mus rattus*)	5
Coypu (*Myocastor coypus*)	4
Crested porcupine (*Hystrix cristata*)	3
Domestic rabbit (*Lepus cuniculus*)	16
Two-toed sloth (*Cholœpus didactylus*)	1
Great gray kangaroo (*Macropus giganteus*)	3
Wallaros (*Macropus robustus*)	1
Red kangaroo (*Macropus rufus*)	2
Black-striped wallaby (*Macropus dorsalis*)	3
Pademelon wallaby (*Macropus thetidis*)	2
Grey's wallaby (*Macropus greyi*)	1
Brush-tailed rock kangaroo (*Petrogale penicillata*)	4
Bridled wallaby (*Onychogale frenata*)	1
Rat-kangaroo (*Æprymnus rufescens*)	4
Flying phalanger (*Petaurus sciureus*)	2
Common phalanger (*Trichosurus vulpecula*)	8
Bandicoot (*Perameles* sp.)	1
Tasmanian wolf (*Thylacynus cynocephalus*)	[illegible]
Tasmanian devil (*Sarcophilus ursinus*)	1

Animals in National Zoological Park, June 30, 1903—Continued.

Name.	Number.
MAMMALS—continued.	
Domesticated and foreign species—Con.	
Australian "native cat" (*Dasyurus* sp.)	4
Echidna (*Echidna aculeata*)	3
BIRDS.	
Strawberry finch (*Sporæginthus flavidiventris*)	4
Painted grass-finch (*Poëphila mirabilis*)	3
Bar-breasted finch (*Munia nisoria*)	[illegible]
Java sparrow (*Padda oryzivora*)	11
Parson finch	4
Piping crow (*Gymnorhina tibicen*)	1
Toucan (*Ramphastos tocard*)	1
Giant kingfisher (*Dacelo gigas*)	[illegible]
Sulphur-crested cockatoo (*Cacatua galerita*)	4
Leadbeater's cockatoo (*Cacatua leadbeateri*)	1
Bare-eyed cockatoo (*Cacatua gym*-[illegible])	1
Roseate cockatoo (*Cacatua roseicapilla*)	8
Yellow and blue macaw (*Ara ararauna*)	3
Red and yellow and blue macaw (*Ara* [illegible])	2
Red and blue macaw (*Ara chloroptera*)	2
Great green macaw (*Ara militaris*)	1
Chattering lory (*Lorius garrulus*)	1
Green paroquet (*Conurus* sp.)	4
Carolina paroquet (*Conurus carolinen*-[illegible])	2
Yellow-naped amazon (*Amazona auro*-[illegible])	2
White-fronted amazon (*Amazona leucocephala*)	3
Double yellow-head (*Amazona oratrix*)	1
Mealy amazona (*Amazona farinosa*)	1
Yellow-shouldered amazon (*Amazona* [illegible])	1
Levaillant's amazon (*Amazona levaillanti*)	2
Barraband's parrakeet (*Polytelis barrabandi*)	1
Rose-hill parrakeet (*Platycercus eximius*)	3
Parrakeet (*Psephotus haematonotus*)	1
Grass parrakeet (*Melopsittacus undula*-[illegible])	7
King parrakeet (*Aprosmictus cyanopy*-[illegible])	1
Cockateel (*Calopsittacus novæ-hollandiæ*)	3
Great horned owl (*Bubo virginianus*)	13
Snowy owl (*Nyctea nyctea*)	3
Barred owl (*Syrnium nebulosum*)	4
Barn owl (*Strix pratincola*)	5
BIRDS—continued.	
Venezuelan owl	1
Screech owl (*Megascops asio*)	1
Bald eagle (*Haliæetus leucocephalus*)	13
Harpy eagle (*Thrasaëtus harpyia*)	1
Golden eagle (*Aquila chrysaëtos*)	6
Wedge-tailed eagle (*Uroaëtus audax*)	1
Crowned hawk-eagle (*Spizaetus coronatus*)	1
Red-tailed hawk (*Buteo borealis*)	10
Cooper's hawk (*Accipiter cooperi*)	1
California condor (*Gymnogyps californianus*)	3
Turkey vulture (*Cathartes aura*)	6
Black vulture (*Catharista atrata*)	1
King vulture (*Gypagus papa*)	1
Lanzarotte pigeon (*Columba livia*)	1
Ring dove (*Columba palumbus*)	12
Wonga-wonga pigeon (*Leucosarcia picata*)	3
Bronze-winged pigeon (*Phaps chalcoptera*)	5
Crested pigeon (*Ocyphaps lophotes*)	2
Nicobar pigeon (*Calœnas nicobarica*)	1
Wild turkey (*Meleagris gallopavo ferus*)	3
Chachalaca (*Ortalis vetula maccallii*)	4
Daubenton's curassow (*Crax daubentoni*)	3
Lesser razor-billed curassow (*Mitua tomentosa*)	1
Peafowl (*Pavo cristatus*)	37
Mountain partridge (*Oreortyx pictus*)	1
Sharp-tailed grouse (*Pediocætes phasianellus*)	2
Sandhill crane (*Grus mexicana*)	2
Whooping crane (*Grus americana*)	1
Sora (*Porzana carolina*)	1
Thicknee (*Œdicnemus grallarius*)	2
Little blue heron (*Ardea cœrulea*)	2
Great blue heron (*Ardea herodias*)	6
Little white egret (*Ardea candidissima*)	1
Black-crowned night heron (*Nycticorax nycticorax nævius*)	10
Australian bittern	1
Boatbill (*Cochlearius cochlearius*)	1
White stork (*Ciconia alba*)	2
Black stork (*Ciconia nigra*)	2
Marabou stork (*Leptoptilus crumeniferus*)	2
White ibis (*Guara alba*)	2
Wood ibis (*Tantalus loculator*)	6
Trumpeter swan (*Olor buccinator*)	5
Whistling swan (*Olor columbianus*)	3
Mute swan (*Cygnus gibbus*)	3

Animals in National Zoological Park, June 30, 1903—Continued.

Name.	Number.
BIRDS—continued.	
Black swan (*Cygnus atratus*)	1
Brant (*Branta bernicla*)	1
Canada goose (*Branta canadensis*)	6
Hutchins's goose (*Branta canadensis hutchinsii*)	1
Chinese goose (*Anser cygnoides*)	2
Greater snow goose (*Chen hyperborea nivalis*)	2
Wood duck (*Aix sponsa*)	4
Mandarin duck (*Dendronessa galericulata*)	5
Australian tree-duck (*Dendrocygna eytoni*)	1
American tree-duck (*Dendrocygna discolor*)	1
Pintail (*Dafila acuta*)	1
Pekin duck (*Anas* sp.)	1
Mallard duck (*Anas boschas*)	2
Common duck (*Anas boschas*)	3
Australian wild duck (*Anas superciliosa*)	1
American flamingo (*Phœnicopterus ruber*)	1
American white pelican (*Pelecanus erythrorhynchos*)	6
Brown pelican (*Pelecanus fuscus*)	5
American herring gull (*Larus argentatus smithsonianus*)	1
Florida cormorant (*Phalacrocorax dilophus floridanus*)	5
Snake bird (*Anhinga anhinga*)	4
Common rhea (*Rhea americana*)	1
Cassowary (*Casuarius australis*)	3
Emu (*Dromæus novæ-hollandiæ*)	3
REPTILES.	
Alligator (*Alligator mississippiensis*)	14
American crocodile (*Crocodilus americanus*)	2

Name.	Number.
REPTILES—continued.	
Painted turtle (*Chrysemys picta*)	6
Musk turtle (*Aromochelys odorata*)	2
Mud turtle (*Cinosternum pennsylvanicum*)	5
Terrapin (*Pseudemys* sp.	1
Gopher turtle (*Xerobates polyphemus*)	2
Box tortoise (*Cistudo carolina*)	1
Three-toed box tortoise (*Cistudo triunguis*)	6
Painted box tortoise (*Cistudo ornata*)	5
Duncan Island tortoise (*Testudo ephippium*)	2
Albemarle Island tortoise (*Testudo vicina*)	2
Brazilian tortoise (*Testudo tabulata*)	4
Iguana (*Iguana tuberculata*)	2
Australian hooded lizard	1
Comb lizard (*Ctenosaura* sp.)	1
Gila monster (*Heloderma suspectum*)	6
Diamond rattlesnake (*Crotalus adamanteus*)	3
Banded rattlesnake (*Crotalus horridus*)	1
Prairie rattlesnake (*Crotalus confluentis*)	5
California rattlesnake (*Crotalus lucifer*)	2
Copperhead (*Ancistrodon contortrix*)	5
Water moccasin (*Ancistrodon piscivorus*)	3
Cuban tree boa (*Epicrates angulifer*)	5
Common boa (*Boa constrictor*)	4
Anaconda (*Eunectes murinus*)	2
Bull snake (*Pityophis sayi sayi*)	2
Pine snake (*Pityophis melanoleucus*)	6
Coach-whip snake (*Bascanium flagelliforme*)	1
Black snake (*Bascanium constrictor*)	6
King snake (*Ophibolus getulus*)	3
Garter snake (*Eutænia sirtalis*)	1
Horn snake (*Farancia abacura*)	1
Water snake (*Natrix sipedon*)	3
Gopher snake (*Spilotes corais couperii*)	3

Animals presented during the fiscal year ending June 30, 1903.

Name.	Donor.	Number.
Hamadryas baboon	Victor J. Evans, Washington, D. C	1
Capuchin	E. H. Plumacher, United States consul, Maracaibo, Venezuela	1
White-throated cebus	Commander H. McRea, U. S. Navy	1
Lion	Officer of the Sudan government, through Dr. H. T. McLaughlin, Omdurman, Sudan.	1
Ocelot	James Deitrick, Pittsburg, Pa	
Do	Prof. C. V. Cusachs, Naval Academy, Annapolis, Md	1
Do	Admiral J. G. Walker, U. S. Navy, Washington, D. C	2
Caracal	E. S. Cunningham, United States consul, Aden, Arabia	1

Animals presented during the fiscal year ending June 30, 1903—Continued.

Name.	Donor.	Number.
Bay lynx	The President	1
Florida wild cat	William H. Mann, Mannville, Fla	1
Coyote	"Recreation," by a subscription fund for benefit of Miss Irene Murray, Peosta, Iowa.	1
Red fox	H. V. Lansdale, Washington, D. C	1
Raccoon	P. W. Nicholson, Washington, D. C	1
Black bear	Dr. C. W. Bowker, United States Revenue-Cutter Service, Washington, D. C.	1
Do	The President	1
Common goat	Master W. H. Mann, Washington, D. C	1
Venezuelan deer	E. H. Plumacher, United States consul, Maracaibo, Venezuela	1
Mexican deer	Company C, United States Marine Corps	1
Collared peccary	E. H. Plumacher, United States consul, Maracaibo, Venezuela	1
Gray squirrel	G. C. Petwin, Washington, D. C	1
Mexican ground squirrel	E. Meyenberg, Pecos, Tex	1
Prairie dog	Dr. J. Price, Philadelphia, Pa	3
Do	Miss Alice Paret, Washington, D. C	1
Woodchuck	Mrs. B. F. Rogers, Washington, D. C	1
White rabbit	Francis E. Mix, Chevy Chase, Md	2
Do	Mrs. W. E. Baum, Washington, D. C	2
Do	William Mason, Washington, D. C	3
White Belgian hare	Edwin A. Newman, Petworth, D. C	3
Black Belgian hare	do	3
Himalayan rabbit	do	3
Silver gray rabbit	do	2
Peruvian cavy	Charles Silas Baker, Washington, D. C	5
Do	Mrs. E. T. Chamberlain, Washington, D. C	2
Hairy-rumped agouti	E. H. Plumacher, United States consul, Maracaibo, Venezuela	2
Common opossum	Miss Ethel Roosevelt, Washington, D. C	1
Do	J. T. and G. A. Norris, Washington, D. C	1
Do	J. and C. Norton, Washington, D. C	1
Wallaroo	Julian Windeyer, Newcastle, New South Wales	1
Do	Henry W. Russell, Newcastle, New South Wales	1
Rat kangaroo	Mr. Garnick, Newcastle, New South Wales	2
Echidna	Major Burnage, Newcastle, New South Wales	1
Yellow-shouldered amazon	E. H. Plumacher, United States consul, Maracaibo, Venezuela	2
Green paroquet	Donor unknown	1
Great horned owl	H. W. Rutherford, Washington, D. C	1
Screech owl	W. V. Cox, Washington, D. C	1
Barn owl	do	1
Venezuelan owl	E. H. Plumacher, United States consul, Maracaibo, Venezuela	2
Bald eagle	H. C. Henricksen, Miami, Fla	1
Do	Commissioner of Fish and Fisheries	1
Golden eagle	Chas. Payne Smith, Colorado Springs, Colo	1
Do	J. M. Harper, Red Rock, N. Mex	1
Cooper's hawk	G. W. Hall, Washington, D. C	1
Red-tailed hawk	A. M. Nicholson, Orlando, Fla	1
Do	Otis Bigelow, Avenel, Md	1
Do	Dr. A. L. Harris, Washington, D. C	1
Do	T. H. Felton, Washington, D. C	1
Turkey vulture	Frank Faust, Washington, D. C	1
Crested pigeon	Mr. Kibble, Islington, New South Wales	2
Australian dove	do	2
Little blue heron	Paul Bartsch, Washington, D. C	1
Australian bittern	Doctor Russell, Newcastle, New South Wales	1

Animals presented during the fiscal year ending June 30, 1903—Continued.

Name.	Donor.	Number.
Tree duck	Frank Underwood, Newcastle, New South Wales	2
Herring gull	Harry Bailey, Washington, D. C	1
Loon	E. G. Pendleton, Augusta Springs, Va	1
Alligator	Carroll Farquhar, Washington, D. C	1
Do	A. M. Reese, Baltimore, Md	2
Do	Dr. W. M. Nihiser, Keedysville, Md	2
Iguana	E. H. Plumacher, United States consul, Maracaibo, Venezuela	3
Hooded lizard	Fitzroy Stacy, Newcastle, New South Wales	1
Horned lizard	W. J. Bogardus, Washington, D. C	1
Do	E. Meyenberg, Pecos, Tex	2
Diamond rattlesnake	W. H. Mann, Interlachen, Fla	1
Prairie rattlesnake	James Fullerton, Red Lodge, Mont	1
Copperhead	M. G. Skinner, Washington, D. C	1
Black snake	Dr. Isaac W. Blackburn, Washington, D. C	1
Coachwhip snake	M. H. Porter, Kissimmee, Fla	1
King snake	A. M. Reese, Baltimore, Md	1
Do	R. C. Neuman, Richland, Ga	1
Hog-nosed snake	E. T. Carrico, Stithton, Ky	1
Do	Miss Virginia Lucas, Charlestown, Va	1
Horn snake	H. C. Henricksen, Miami, Fla	1

Summary.

	Number.
Animals on hand July 1, 1902	883
Accessions during the year	170
Total	1,353
Deduct loss (by exchange, death, and returning of animals)	353
On hand June 30, 1903	1,000

Respectfully submitted.

Frank Baker, *Superintendent.*

Mr. S. P. Langley,
Secretary of the Smithsonian Institution.

Appendix V.

REPORT OF THE WORK OF THE ASTROPHYSICAL OBSERVATORY FOR THE YEAR ENDING JUNE 30, 1903.

Sir: The kinds and amounts of the Observatory property are approximately as follows:

Buildings	$6, 300
Apparatus	36, 900
Library and records	6, 460
Total	49, 660

During the past year the acquisitions of property of the kind just enumerated have been as follows:

(a) *Apparatus.*—Astronomical and physical apparatus has been purchased at an expenditure of $3,600, the chief pieces so procured being in connection with the installation of a long-focus horizontal reflecting telescope of 20 inches aperture and 140 feet focus.

(b) *Library and records.*—The usual periodicals have been continued and additional ooks of reference have been purchased, while 184 volumes of periodicals and books of reference have been bound. There has been expended for these several purposes $460, of which sum $254.50 was chargeable to the appropriation for the fiscal year ending June 30, 1902.

No repairs of buildings worthy of note have been made during the year, but the Observatory inclosure was enlarged for the better accommodation of the great horizontal telescope by removing 39 feet at the western end of the south fence to a position 20 feet to the south.

No noteworthy losses of property have occurred.

The Work of the Observatory.

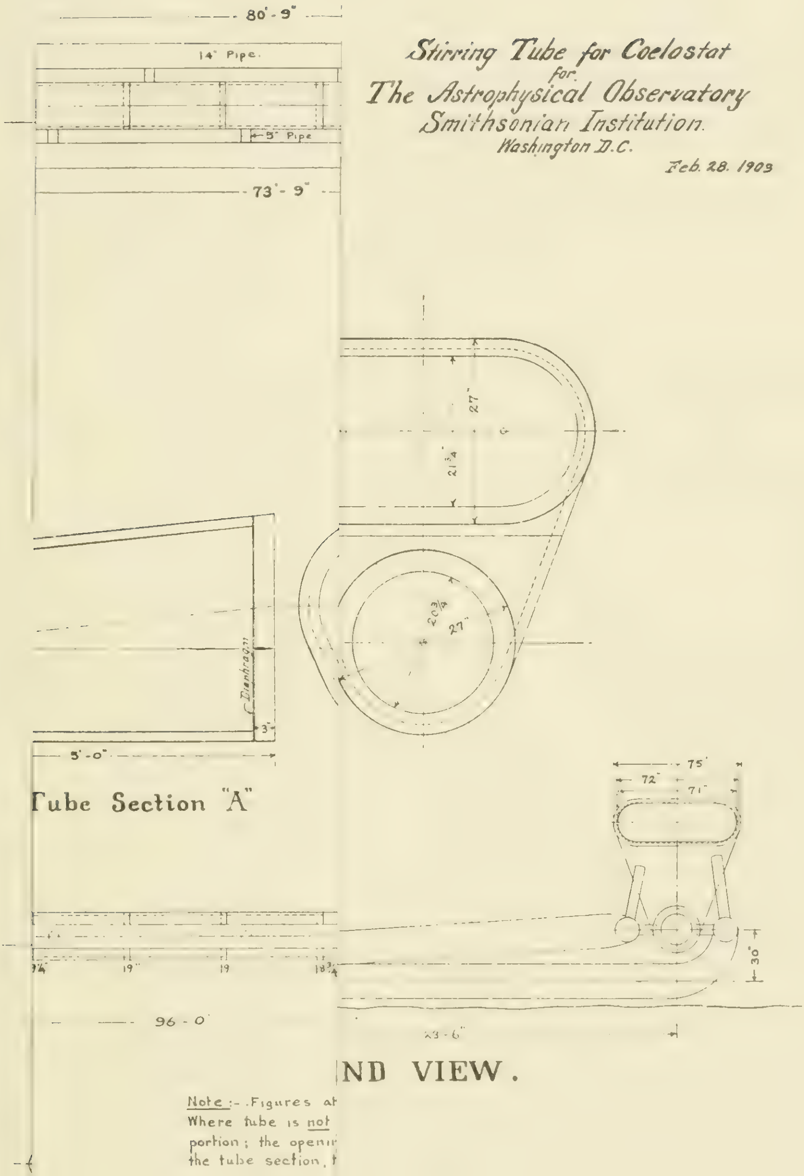
For convenience the work of the Observatory will be considered under three heads, as follows:

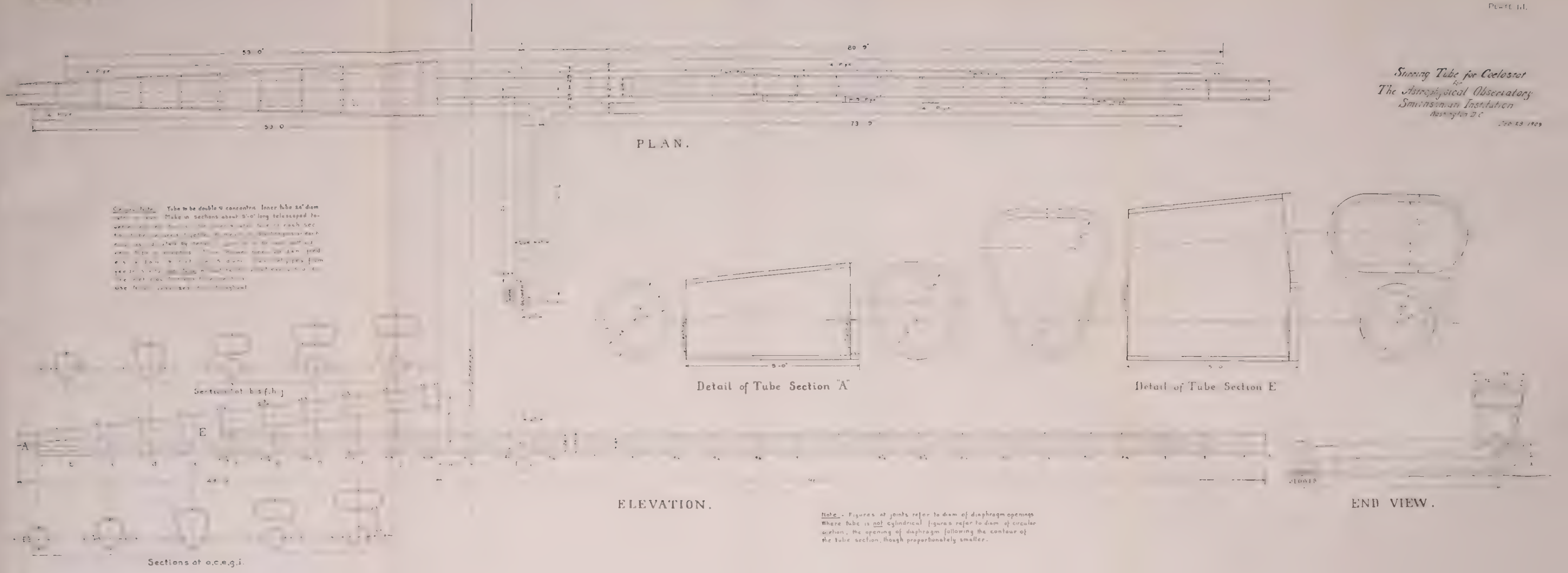
1. Publications and miscellaneous matters.
2. The new horizontal telescope and other apparatus.
3. Investigations relating to the atmospheric absorption and to the solar constant of radiation.

1. *Publications and miscellaneous matters.*

Eclipse report.—A report of the expedition to Wadesboro, N. C., to observe the total solar eclipse of 1900 has been greatly delayed, but is now complete and in the hands of the printer, and it is expected will be distributed in the coming fiscal year. It will contain numerous plates illustrative of the work of the expedition and especially of the photography of the inner coronal region with the 135-foot focus lens, by Mr. Smillie.

Miscellaneous work.—The Observatory staff has continued, as heretofore, to furnish


Stirring Tube for Coelostat
for
The Astrophysical Observatory
Smithsonian Institution.
Washington D.C.
Feb. 28. 1903
80'-9"
14" Pipe.
5" Pipe
73'-9"
27"
21 3/4
20 3/4
27"
Diaphragm
3"
5'-0"
Tube Section "A"
75"
72"
71"
30"
19"
19
18 3/4
96-0
ND VIEW.
Note :- Figures at
Where tube is not
portion ; the openi
the tube section, t


Sighting Tube for Coelostat
for
The Astrophysical Observatory
Smithsonian Institution
Washington D.C.
Feb 23 1909
53' 0"
80' 9"
73' 9"
PLAN.
Tube to be double & concentric. Inner tube 24" diam
Make in sections about 5'-0" long telescoped to-
Sections at b.d.f.h.j.
Detail of Tube Section "A"
Detail of Tube Section E
5'-0"
ELEVATION.
END VIEW.
Note. - Figures at joints refer to diam of diaphragm openings
Where tube is not cylindrical figures refer to diam of circular
portion, the opening of diaphragm following the contour of
the tube section, though proportionately smaller.
Sections at a.c.e.g.i.

occasional assistance in matters of a physical or astronomical nature connected with the Institution. Among experimental undertakings of this kind may be mentioned the rough measurement of the absorption of certain substances for infra-red radiations, made at the request of some correspondents of the Institution.

Personnel.—No changes have been made in the permanent staff of the Observatory. Doctor Gilbert completed his temporary services on August 15, 1902, and Dr. J. R. Benton filled a temporary appointment from September 16, 1902, to November 30, 1902.

2. *The new horizontal telescope and other apparatus.*

Referring to my report of last year, it will be recalled that preliminary attempts had been made to measure the absorption of the gases of the solar envelope by bolographic study of an enlarged solar image, and that it was your intention to continue the work so as to include the bolographic study of sunspot spectra, but that these researches were temporarily laid aside till a more suitable arrangement for forming and guiding the solar image could be obtained. Much study and experiment has been devoted to this matter in the past year, and as a result a horizontal reflecting telescope of 20 inches aperture and 140 feet focus has been obtained, and provided with a tube in which the air can be thoroughly stirred to overcome "boiling," in accordance with the experiments reported last year. To "feed" this horizontal telescope a modification of the coelostat has been devised which is believed to be before untried, and which renders this simple instrument so well adapted for the purpose of solar research that it is hoped that the device will approve itself elsewhere.

A large instrument of this type has been constructed by the J. A. Brashear Company, of Allegheny, Pa., and will form a part of the Astrophysical Observatory exhibit at the Louisiana Purchase Exposition at St. Louis in 1904. All the above apparatus, including the coelostat, long-focus mirror, tube and air-stirring devices, and three great piers for the coelostat, concave mirror, and bolometric apparatus for the study of the image, are now in use. The accompanying illustration, Pl. IV, shows the great coelostat and a portion of the tube which incloses the beam from the coelostat to the concave mirror, 55 feet north, and thence south and under the coelostat to the plane of the focal image. It will be noted by the reader that the beam is reflected in the plane of the meridian from the first plane mirror mounted on a polar axis which turns half as fast as the earth, and that a second reflection occurs at the surface of a second plane mirror, adjustable about two horizontal axes, and also capable of moving bodily, by means of tracks, east and west and north and south. Thus the second mirror can receive the beam at any hour of any day of the year, and reflect it in any desired direction. In practice a nearly horizontal and northerly direction is chosen.

Pl. III is from the working drawing of the tube, which is an acute V in general shape, with a longer branch of circular cross section extending from the concave mirror on the northern pier to the focus, 140 feet distant on the southern, and with a shorter branch uniting with the longer at its northern end, but proceeding southward and inclined upward at an angle of 6° and ending at the coelostat, 55 feet distant. This shorter branch is circular at its northern end, but broadens out to an elliptical cross section, as shown, in order to inclose the beam for the east and west positions of the second coelostat mirror. Both branches of the tube are of galvanized iron, with two walls separated by an air space 1½ inches thick all around. The inner tube is blackened and is provided with diaphragms.

In Plate III is also shown the air ducts which are employed for stirring in the great tube. Starting from the blowing engine, which is a 29-inch circular fan blower, with direct-connected 2½-horsepower electric motor, making 700 revolutions per minute, the blast is carried by a 20-inch main to a point near the middle of the tube, where

the air duct branches into two 14-inch tubes, which proceed north and south respectively and communicate by 5-inch pipes to the interior of telescope tube. At points intermediate with these other 5-inch pipes lead out of the telescope tube and thence by return mains to the suction end of the blower, and thus the same air is continually being churned about through the entire system.

To prevent the blowing engine and the city traffic from communicating prejudicial tremors to the apparatus, three deep and massive piers have been constructed, supporting respectively the coelostat, the long-focus concave mirror, and the spectro-bolometric apparatus used to investigate the solar image. Each pier is contained in a pit originally 12 feet square and 10 feet deep, but supported by retaining walls of grouting 1 foot thick, so as finally to leave a cubical-shaped pit 10 feet on a side. At the bottom is a layer of sand 2 feet deep, and on this a base of grouting 2 feet thick and 9 feet square, supporting the brick pier, which is built to the surface of the ground 7 feet square, with 18-inch walls on the four sides and a 13-inch wall north and south through the center. Over all is the capstone, 8 feet north and south, 7 feet east and west, and 7 inches thick. In the case of the coelostat pier a two-walled brick superstructure is carried up to the top of the horizontal tube to support the base plate of the coelostat. In spite of all these precautions I regret to report that the disturbance from passing traffic and even distant railroad trains has not been sufficiently eliminated, and requires further measures to be taken to overcome the almost unconquerable difficulties of the site.

Owing to prolonged cloudy weather, the apparatus had not been fully tried between the time of its installation, about June 1, and the close of the period covered by this report, but, so far as preliminary experiments have shown, the whole promises to be a valuable equipment if the tremors due to the site can be corrected.

The sensitive galvanometer.—Referring to portions of my reports of preceding years describing the construction and installation of a highly sensitive galvanometer, I regret that attention has been diverted this year to other matters so completely that comparatively little work has been done with it. In the fall of last year an apparatus was arranged to measure the heating effect of the brighter stars by its aid, but unfortunately communication with the mercurial air pump had so quickly blackened the silvered galvanometer mirrors that this, together with their almost microscopic size, made it impossible to read the galvanometer by artificial light. After several trials numerous mirrors were platinized by electrical discharge in vacuo and the galvanometer was provided with mirrors of this kind, but immediately after the experiments were discontinued to take up work on the provision of the great horizontal telescope. It is hoped to provide for the use of this special galvanometer in spectrum work on the solar image, especially in connection with sun spots, and perhaps upon the heat of the stars.

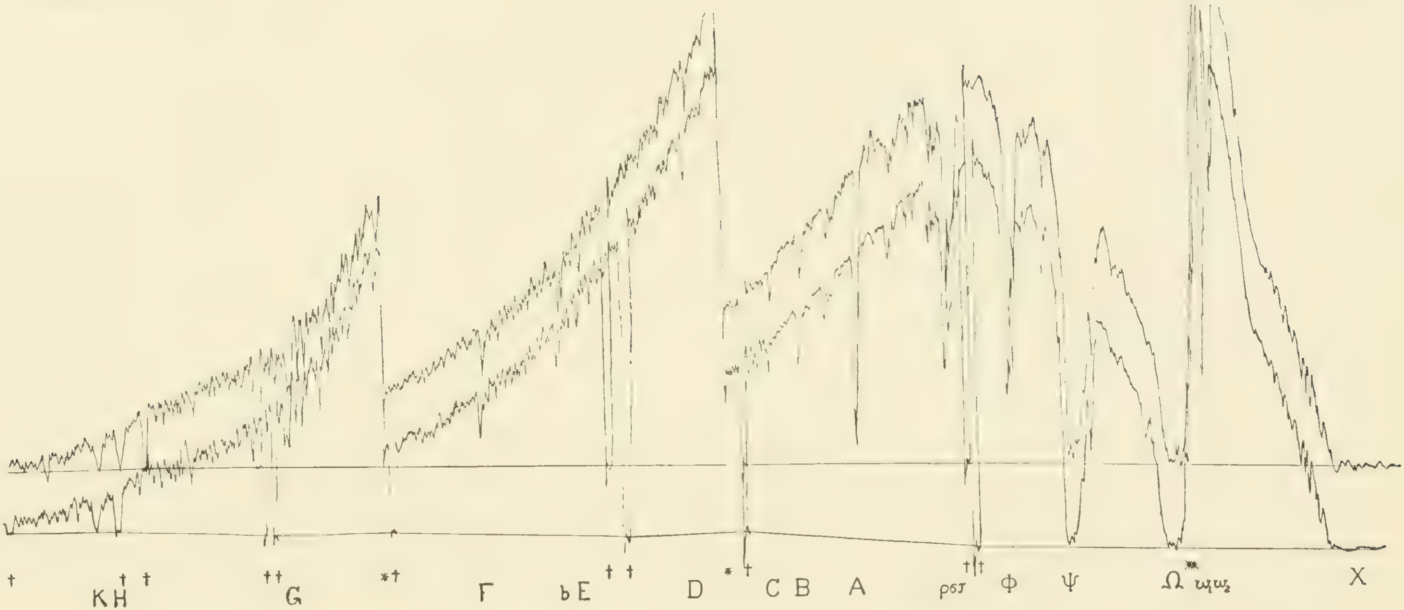
3. *Investigations relating to the solar constant of radiation.*

Referring to my last year's report, the bolographic measurements of atmospheric absorption then described have been continued chiefly in the hands of the junior assistant, Mr. Fowle, with improved arrangements and with more complete and exact results. In connection with them the absorption of the radiation in all parts of the apparatus has been determined frequently, and measures of the total solar radiation by the actinometer or pyrheliometer have been made also. From these several kinds of data the solar constant of radiation, or rate of receipt of solar energy at the outer limit of our atmosphere, has been computed for a number of the best days.

Improvement of bolographs.—Before giving these values, I invite attention to Plate V, which shows three superposed energy curves of the prismatic solar spectrum. Such bolographic curves are now obtained covering the region of spectrum from

THE LARGE CŒLOSTAT WITH SECOND MIRROR, SMITHSONIAN ASTROPHYSICAL OBSERVATORY.

PLATE V.



BOLOGRAPHIC ENERGY CURVES OF THE SOLAR SPECTRUM OF A 60° GLASS PRISM. OBSERVATIONS OF APRIL 17, 1903.

† Beam cut off by shutter to give position of zero line. * Slit diminished by interposing grill diaphragms. ** Slit increased by removing grill diaphragms.

wave length 0.375μ to wave length 2.5μ in about twenty-five minutes of time. This region extends from beyond the line "L," or farther than the eye can see without special means in the ultra violet, through the whole visible spectrum, and on through the visible but very intense upper infra-red spectrum as far as glass is transparent. It includes about $\frac{999}{1000}$ of the solar radiation which reaches the earth's surface, and so far as experiment has shown, within 1 and 2 per cent of all that reaches the outer layers of the earth's atmosphere lies within this spectral region.

It is only since January, 1903, that the apparatus has been so far perfected as to include in the regular bolographic work the important portion lying between 0.375μ and 0.47μ, and in Plate V readers may see for the first time, as the bolometer recognizes them, the general features of the violet solar spectrum so familiar in photographic spectra. It is, of course, impossible to show the finer details when the bolometer passes through the whole visible and upper infra-red spectrum in less time than was occupied in passing from through a fourth of the upper infra-red alone in preparing the detailed map published in 1900; but nevertheless in a rough comparison of three curves it was seen that as many as 325 of the Fraunhofer lines were discriminated by the bolometer as it passed over them thus rapidly. As remarked last year, scarcely any "drift" of the galvanometer is now experienced, and, indeed, it is sometimes possible to take bolographs for a month without readjusting the bolometric circuit in any way. This excellent behavior is principally due to the improved rheostat and to the 16-coil type of galvanometer, both of which were mentioned on page 87 of last year's report.

Transmission of the atmosphere.—From series of such bolographs as are described at page 89 in my last year's report, coefficients of transmission of the atmosphere are obtained. It is now customary to compute them for more than 30 points in the spectrum between wave lengths 0.37 μ and 2.5 μ, of which 24 are at wave lengths where there are no prominent atmospheric bands and the others within such bands. The reduced observations take such a form that they may be graphically platted as straight lines whose angle of inclination is a measure of the transmission coefficient of the air at the given wave length. It is the exactness with which the reduced observations from the bolograph fall upon such straight lines which furnishes the principal criterion of their value. To show how close this agreement is on the best days, I invite attention to Plate VI, which gives for several wave lengths the reductions of the observations of March 25 and 26, 1903, respectively. Ordinates are logarithms of heights of the bolographic curves at the selected wave lengths and abscissæ are air masses.

The circles represent observations of March 25 and crosses those of March 26. Lines I and II are for a wave length of 1.027 μ; III and IV at 0.656 μ; V and VI at 0.468 μ, and VII and VIII at 0.395 μ. On nearly all days of observation it is found that the forenoons yield a less regular series than the afternoons, and it appears as if the air became clearer and clearer till a little after noon and then remained substantially unchanged on the best days till 4 or 5 o'clock p. m. It is therefore the practice here to use only afternoon observations in determining atmospheric transmission. The forenoon observations are distinguished in Plate VI by being connected by dotted lines.

Notable decrease in the transparency of the air in the present calendar year.—From numerous determinations of the transmission of the air for solar radiations, a striking diminution of the transmission has been noted in the best days of this year as compared with last year. To illustrate this difference I give the following table:

TABLE 1.—*Coefficients of atmospheric transmission for radiation from zenith sun.*

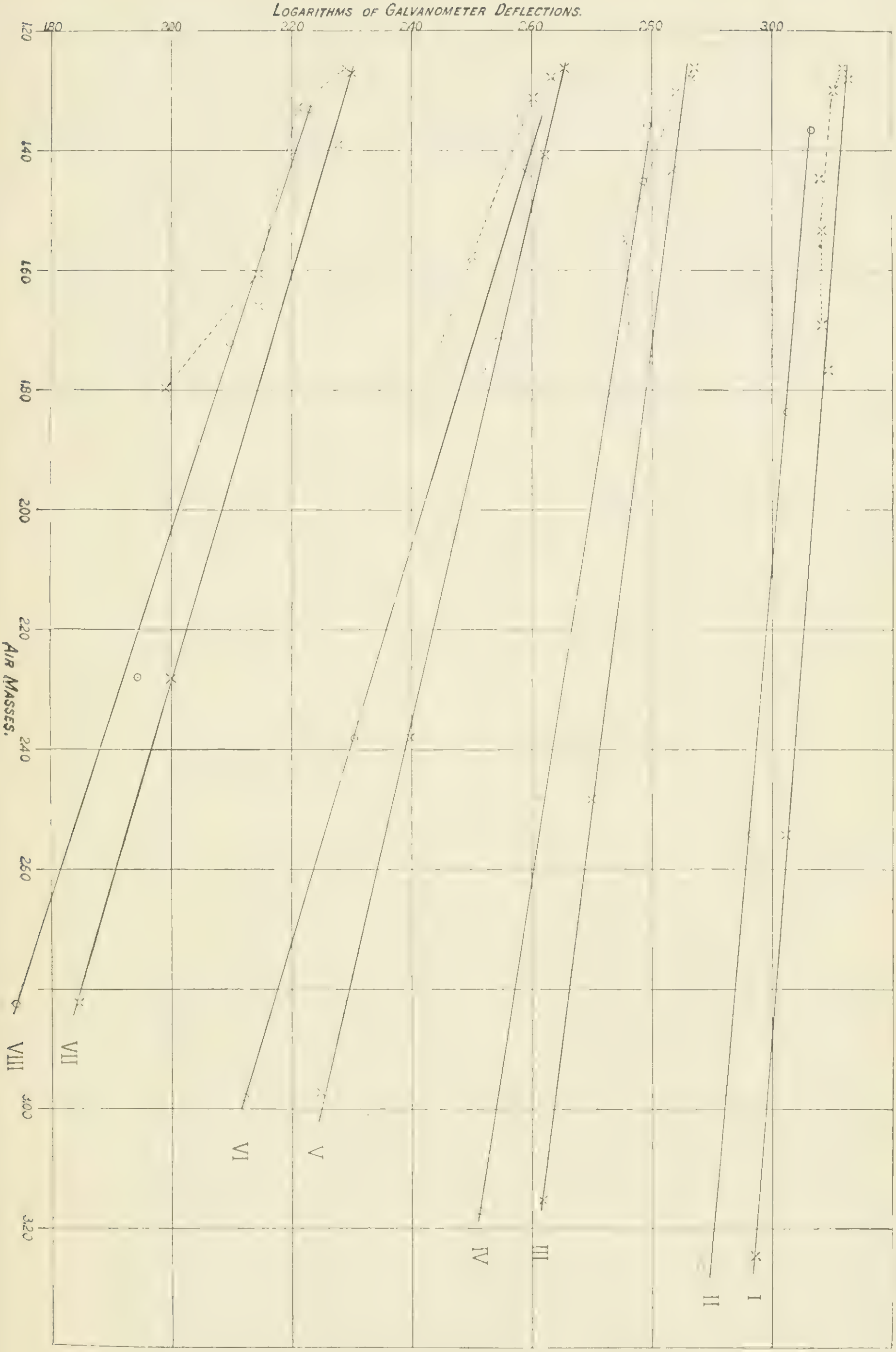
Wave length	0.40	0.45	0.50	0.60	0.70	0.80	0.90	1.00	1.20	1.60	2.00
Date.	Transmission coefficients for unit air mass.										
1901.											
October 25		......	0.81	0.82	0.89	0.94	......	0.95	0.96	0.95	......
November 2			.80	......	.87	.92	......	.91	.95	.91	......
1902.											
March 21			.83	.80	.84	......	......	....	......	.87	.....
May 8			.89	.77	.90	.94	......	.95	.94	.91	......
September 11		......	.80	.78	.87	.89	0.92	.92	.94	.93	......
October 9		......	.70	.78	.84	.87	.89	.90	.91	.93	......
October 15		......	.73	.78	.86	.89	.90	.91	.93	.96	0.94
October [illegible]			[illegible]	.58	.79	.82	......	.86	.90	.91	......
October [illegible]			.84	.82	.88	.91	.93	.94	.94	.95	.....
November 15		......	.75	.79	.83	.89	.91	.92	.93	.95	.96
1903.											
February [illegible]	0.47	0.64	.66	.72	.76	.80	.83	.85	.86	.90	.92
February 25	.48	.60	.66	.68	.74	.83	.88	.90	.93	.93	.92
March [illegible]	.40	.48	.66	.73	.79	.84	.87	.89	.92	.96	.96
March [illegible]	.47	.50	.57	.66	.72	.76	.79	.81	.84	.88	.89
March 26	.52	.58	.62	.68	.77	.80	.81	.83	.85	.89	.90
April 17	.55	.60	.69	.77	.80	.82	.87	.90	.94	.97	.97
April 28	.39	.52	.56	.64	.71	.74	.76	.78	.82	.88	.89
April 29	[illegible]	.49	.56	.66	.72	.76	.77	.80	.83	.88	.90
July 7	.42	.60	.66	.69	.77	.82	.85	.86	.88	.89	.86
General mean	......	......	.700	.730	.808	.847	.856	.884	.903	.920	.919
Mean of 1902	......	......	.765	.769	.857	.897	.910	.921	.933	.930	.950
Mean of 1903	.484	.557	.627	.692	.753	.797	.825	.847	.874	.909	.912
Percentage difference between mean of 1903 and that of 1901–2	......	......	20	10	13	12	10	8.4	6.5	2.3	4.1

It is to be regretted that the earlier work did not reach up so far in the violet as we now observe, but the trend of the observations makes it appear that the transparency of the air for the extreme visible violet rays may be 30 per cent less than last year, and that the transparency for the visible and infra-red spectrum as a whole has diminished by 10 per cent. If this change is widespread it should be likely to influence climate, and that it is widespread the falling off of actinometric observations both in this country and Europe, as reported by several observers, would seem to indicate.

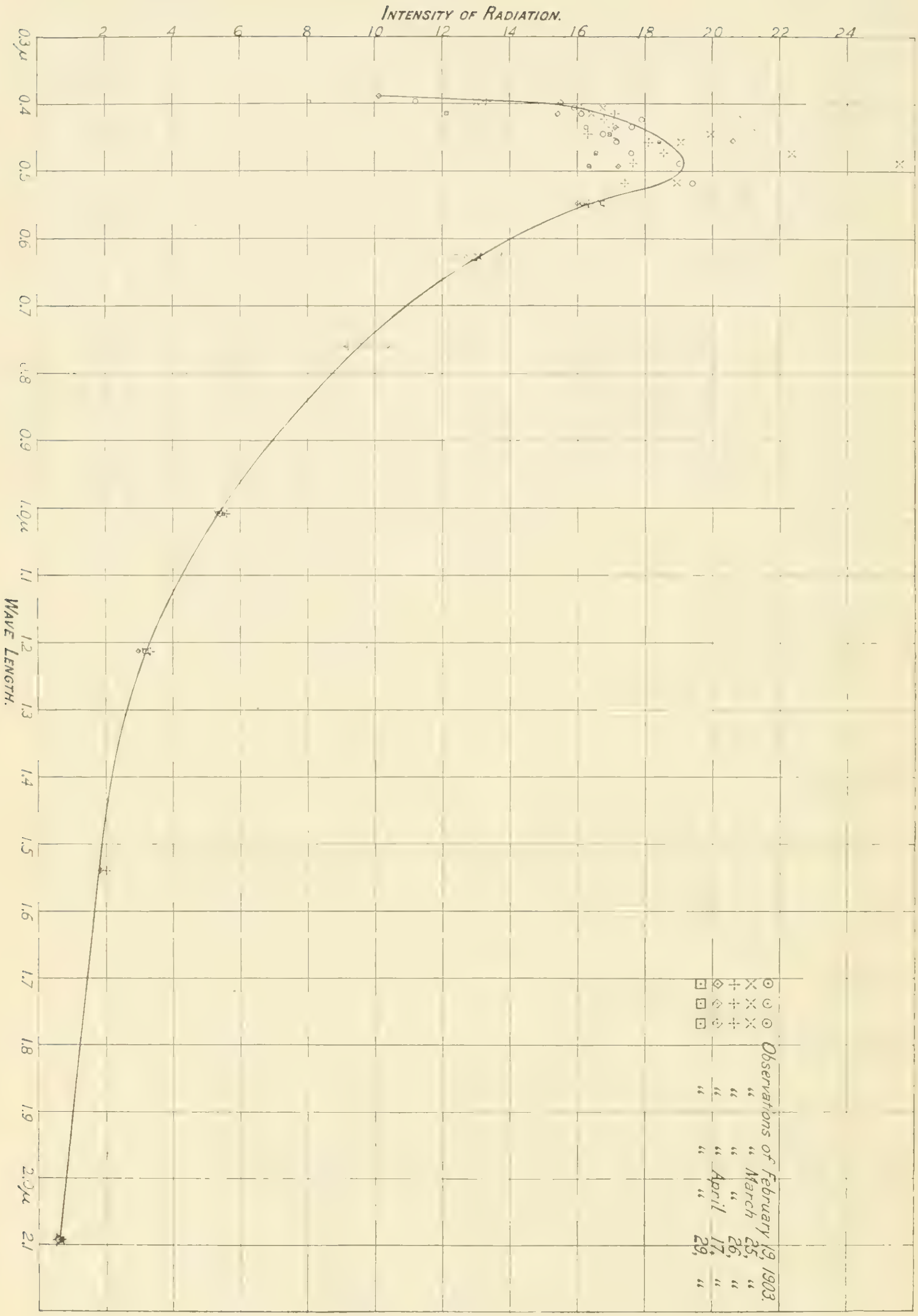
Selective atmospheric absorption.—Referring to fig. 3, page 89, of my last year's report, the depression at a wave length of 0.58μ in the curve there shown would appear less marked in the more recent results, owing to the great decrease in transparency for the blue and violet rays; but nearly all recent work gives evidence of bands of diminished atmospheric transmission at wave lengths 0.43μ, 0.48μ, and 0.58μ.

Interesting results have been obtained in respect to the atmospheric transmission within the great bands of water vapor and oxygen, and it has been found, in confirmation of the accuracy of the observations, and especially of the exponential formula employed in reducing them, that the values of transmission coefficients within the water-vapor bands of the infra-red are such as would very nearly obliterate these bands from an energy-spectrum curve corrected to represent the distribution of solar radiation in the spectrum outside the earth's atmosphere.

Actinometric and pyrheliometric observations.—In the autumn of 1902 an alcohol acti-



TRANSPARENCY OF THE ATMOSPHERE FROM BOLOGRAPHIC OBSERVATIONS.



DISTRIBUTION OF RADIATION IN THE NORMAL SOLAR SPECTRUM OUTSIDE THE EARTH'S ATMOSPHERE.

nometer of M. Crova's well-known design, and constructed under M. Crova's personal direction, was received at the Observatory. This is a secondary type of instrument, requiring standardization by comparison with some other radiation-measuring instrument whose constants can be determined. Such an assumed standard was constructed here by inclosing the cylindrical bulb of a mercury thermometer in a flat round box of very thin copper filled with mercury, nickeled on the back and sides, blackened with platinum deposit in front, and situated in the center of a much larger hollow, thick-walled wooden sphere coated with bright tin foil within, and provided with a measured aperture opposite the front of the copper box, to which the solar beam was led through a diaphragmed blackened tube. Such an instrument is essentially the pyrheliometer of Pouillet, as advantageously modified by Tyndall by the employment of mercury instead of water, but is rendered still more quick in its action by the use of copper instead of the iron employed by Tyndall, and partakes somewhat of the character of a perfect absorber or "black body," because inclosed in the tinfoil coated hollow sphere. The water equivalent of the instrument was determined by repeated calorimetric measurements. In use it has apparently worked perfectly, responding so quickly to the heating of the solar rays that the rise of temperature in the first 20 seconds after exposure is within two or three hundredths of a degree as great as in the following 20-second intervals.

Nevertheless there is a doubt as to the accuracy of this and, as I think, of all instruments thus far used to measure the total solar radiation, from the fact that they one and all receive the beam upon a front surface, which must necessarily get warmer than the rear portion of the instrument, where the rise of temperature is observed, and hence must lose a portion of the heat by a greater convection and radiation than that which takes place after insolation has ceased. Thus a portion of the heat always escapes measurement, and there is no ready way of knowing what its amount is. It has been sought to devise here some type of standard pyrheliometer to which this objection does not apply, and it is believed that such an instrument has been found, although its construction is not yet complete. In principle it depends on receiving the radiations within a hollow chamber or "black body" and carrying away the heat by a continuous current of liquid, and the instrument, if successful, can be employed as a continuous self-recording pyrheliometer.

Meanwhile repeated comparisons have made it sure that both the Crova actinometer and the mercury pyrheliometer give readings proportional to the solar radiation, though there still remains some doubt as to the absolute magnitudes. Accordingly one or both of these instruments have been read on days when the transmission of the air has been determined, and these two kinds of data have been employed to compute the solar constant of radiation or rate of receipt of solar radiation outside the earth's atmosphere.

THE SOLAR CONSTANT.

This important quantity has been studied by the method you have devised and described in the report of the Mount Whitney Expedition, and in a recent article in the Astrophysical Journal for March, 1903. As employed here the method consists in producing bolographs of the solar spectrum, correcting the form of these for instrumental absorption, and again for atmospheric absorption, and then multiplying the rate of receipt of solar radiation at the earth's surface, as measured by the actinometer, by the ratio of the areas included under the bolographic curves, corrected for atmospheric absorption and uncorrected, respectively.

The work here has been more in the way of developing the method of study and obtaining experience in its use than in the expectation of measuring with certainty the solar constant itself, for (as you have elsewhere observed), whereas it is in other kinds of observation almost a certainty that the mean of a series of observations is more trustworthy than any single one, here a single observation made without inter-

vening absorption would outweigh any number requiring correction for atmospheric absorption, and the values observed through smallest air masses are the most trustworthy. It follows that values obtained at a low altitude like that of Washington are necessarily too small, owing to the difficulty of allowing with accuracy for the absorption of the great thickness of air above the observer.

There has been incorporated in the act appropriating for the support of the Astrophysical Observatory during the fiscal year ending June 30, 1904, a provision for high-altitude observations. In anticipation it may be said that apparatus for that purpose has been ordered.

Although, therefore, uncertainty attaches to the actual values determined here and to be given below, still it is probable that they are relatively comparable among themselves when we consider the apparent accuracy both of the observations and the exponential formula used in reducing them, as illustrated in Plate VI, and the fact that the application of coefficients of atmospheric transmission determined similarly would practically obliterate the great selective absorption bands in computing the form of the solar energy curve outside the atmosphere.

REDUCED OBSERVATIONS OF THE SOLAR RADIATION CONSTANT.

In the following table will be found such computations of the solar constant as were made up to July 1, 1903. The bolographs on which they depend extend for the most part from $0.375\,\mu$ to $2.5\,\mu$, and thus include practically all the solar radiation which reaches the earth's surface.[a]

A correction of about 1 per cent has been added, representing the best estimate which could be made of the excess of energy beyond these limits outside the earth's atmosphere. All the results depend on the constant of the pyrheliometer, and may therefore be subject to multiplication by a constant factor to be subsequently determined. Comparing the values obtained with those which you have given in the Mount Whitney report of 3 calories, it will be seen that they are about 25 per cent smaller, and that the difference does not appear to depend on the transmission coefficients, but rather seems chiefly due to a difference in actinometry.

Thus you have stated the usual actinometer reading at Allegheny, Pa., for clear blue sky at 1.7 calories,[b] while the very highest value obtained here is 1.44 calories. Much lower values are reported from recent observations of Mr. Kimball, of the United States Weather Bureau, at Asheville, N. C., and at Washington, so that on the whole the question of absolute actinometry seems a very open one.

Turning next to the relative values of the solar constant, it is seen that there is generally good agreement of the results prior to March 26, 1903, and that since that date there has been a decrease of about 10 per cent in the computed constant. No reason for this is known, as some of the best observations were before and others since March 25, those of February 19, March 25, March 26, and April 29 being considered to have most weight. February 25 was a most extraordinary day as regards absence of water vapor absorption. Never since bolographs have been taken here have the great infra-red water-vapor bands $\varphi\ \Psi\ \Omega$ been observed so feeble as on February 19.

[a] The observations of October, 1902, which reached only to 0.48μ, have been corrected by means of later work and are therefore of less weight.

[b] Report of the Mount Whitney Expedition, p. 32.

TABLE 2.—*Values of the solar constant of radiation from bolographic studies at Washington.*

Date.	Hour angle, west.	Air mass.	Calories per square centimeter per minute. At the earth's surface.	Calories per square centimeter per minute. Outside the atmosphere.	Solar constant corrected for mean distance of sun.
1902.	*h. m.*		*Cal.*	*Cal.*	
October 9	0 06	1.425	1.42	2.20	2.19
October 15	1 31	1.624	1.44	2.21	2.19
October 22	3 01	2.415	1.30	2.18	2.16
1903.					
February 19	1 01	1.642	1.35	2.34	2.28
Do	2 22	2.003	1.20	2.31	2.25
March 3	0 59	1.429	1.34	2.31	2.26
March 25	2 01	1.451	1.19	2.29	2.27
March 26	1 57	1.438	1.16	2.11	2.10
Do	2 59	1.751	1.05	2.09	2.07
April 17	2 45	1.463	1.19	1.97	1.99
April 28	1 07	1.145	1.29	2.23	2.27
April 29	2 26	1.308	1.05	1.93	1.97
General mean					2.167
Mean of results prior to March 26, 1903					2.229
Mean of results after March 26, 1903					2.080

THE FORM OF THE SOLAR-ENERGY CURVE OUTSIDE THE ATMOSPHERE AND THE INFERRED TEMPERATURE OF THE SUN.

Plate VII includes a number of curves which represent on the normal wave-length scale the distribution of energy in the solar spectrum outside the earth's atmosphere. They are computed from prismatic energy curves by aid of the coefficients of instrumental and atmospheric absorption and the known dispersion of the prism. It will be seen that these recent studies indicate the position of the maximum ordinate at a wave length of about 0.49 μ, or between green and blue of the spectrum, and that there is a fairly close agreement between the different days' work. The principal differences occur in the blue and violet spectrum, and are to some extent caused by the rapid deterioration of the reflecting power of the silvered surfaces in this region, which renders very frequent measurements of instrumental absorption necessary, and even then hardly sufficient.

Paschen and others have established an empirical equation connecting the absolute temperature T with the wave length of maximum energy λ_{max}, which is as follows:

$$\lambda_{max}\ T = \text{CONSTANT}.$$

The constant in this equation has been determined by Paschen, Lummer, Pringsheim, and others, to be about 2,900 for an "absolutely black body," or perfect radiator, and ranging as low as about 2,600 for bright platinum. Using the former value, we may say that it appears that the radiation of the solar beam outside the earth's atmosphere has its maximum energy at the same wave length as a perfect radiator of the assumed temperature of 5,920° absolute.

SUMMARY.

The operations of the year have consisted chiefly: First, in the provision and successful installation of a horizontal reflecting telescope of 20 inches aperture and 140

feet focus, fed by a new form of two-mirror coelostat, and employed with a provision for "churning" the air on the path of the beam. This instrumental equipment is to be used for bolographic study of the solar image, and especially sun-spot energy spectra and the absorption of the solar envelope. Second, in the continuation, with improved bolographic apparatus, of studies of the solar-energy spectrum and the absorption of radiation in the atmosphere.

As the most notable result of the studies of atmospheric absorption, it appears that the average transmission of the air of Washington for all wave lengths for the best days of 1902–3 has been as much as 10 per cent less than for the best days of 1901–2, while the decrease of transparency in the violet is very much greater. There is no evidence that this remarkable decrease is due to water vapor. Indeed, it has been well observed on the very driest days.

Inquiries have been made of the Observatory as to whether the blight of the wheat and barley crops could be attributed to any decrease in the ultraviolet radiation of the sun, but the Observatory was able only to state the fact that such a decrease had been observed.

It is probable that something like this affected the actinometric observations recorded by Crova in the years following the great eruption of Krakatoa, though whether the smaller one of Mont Pelee can be associated with it is uncertain. There is no evidence yet obtainable of how general this absorption is at different parts of the globe, but it is, perhaps, the most notable single result of our past year's experiments, and is eminently in the line of the work you have anticipated for the Astrophysical Observatory, in furnishing data of importance to the national interests in agriculture, and in estimating the influences which may affect past and coming harvests.

Respectfully submitted.

C. G. Abbot,
Aid, Acting in Charge Astrophysical Observatory.

Mr. S. P. Langley,
Secretary of the Smithsonian Institution.

Appendix VI.

REPORT OF THE LIBRARIAN.

Sir: I have the honor to present the report on the operations of the library of the Smithsonian Institution for the fiscal year ending June 30, 1903.

In the following table is shown the number of volumes, parts of volumes, pamphlets, and charts recorded in the accession books of the Smithsonian deposit, Library of Congress:

	Quarto or larger.	Octavo or smaller.	Total.
Volumes	464	1,384	1,848
Parts of volumes	14,288	6,994	21,282
Pamphlets	500	3,304	3,804
Charts			379
Total			27,313

The accession numbers run from 445524 to 452465.

A small number of these publications are assigned temporarily to the library here for the use of the staff of the Institution and Museum, the greater quantity being sent direct to the Library of Congress.

These sendings required about 200 boxes and 20 bags and packages, and are estimated to have amounted to the equivalent of 9,200 octavo volumes. The publications sent in this way are independent of those transmitted by the Bureau of International Exchanges, and do not include public documents presented to the Smithsonian Institution, which are sent to the Library of Congress without stamping, credit there being given to the country sending.

For several years prior to the removal of the Library of Congress to its new building a large number of the scientific series bearing upon the work of the Institution were retained, owing to the crowded condition of the Library of Congress in its old quarters at the Capitol. During the past year it has been found possible to get these out, have them taken off the Museum record, and checked on the accession book and sent to the Library of Congress. These sets, series, and volumes were forwarded in 167 boxes, estimated to contain about 6,680 octavo volumes, making a total sending to the Library of Congress for the year of about 15,880 volumes.

The libraries of the Secretary, Office, and Astrophysical Observatory have received during the year 409 volumes, pamphlets, and charts and 1,625 parts of volumes, making a total of 2,034, and a grand total, including books for the Smithsonian deposit, of 29,347. The serial publications entered on the card catalogue number 24,630.

The universities at the following places have sent inaugural dissertations and academic publications:

Baltimore (Johns Hopkins).
Basel.
Berlin.
Breslau.
Erlangen.
Freiburg.
Halle a Saal.
Heidelberg.
Helsingfors.
Ithaca (Cornell).
Jena.
Kazan.
Konigsberg.
Leipzig.
Marburg.
Oxford.
Philadelphia (University of Pennsylvania).
Rostock.
St. Petersburg.
Strasburg.
Toronto.
Toulouse.
Utrecht.
Vienna.
Washington, D. C. (Catholic University).
Zurich.

Owing to the large number of series and parts of sets culled from the Museum library and sent to the Library of Congress for the Smithsonian deposit during the year the Office has been occupied with the checking off and making memoranda for the completing of these sets. While this has taken a great deal of time, the policy carried on from year to year of increasing the library by exchange has been continued, and though, for the above reason, there is quite a decrease in the number of letters written for new exchanges and for completing series already in the library, the total reached 714. Two hundred and sixty-five periodicals were added to the receipts and 239 defective series were either completed or partly completed, depending upon the publisher's ability to supply the numbers needed. Where certain numbers of periodicals are reported as missing, a request that they be supplied is made on a postal card and corresponding cards are sent in acknowledgment of receipts. During the year 654 numbers were asked for and 424 supplied.

The books in the reference room containing the proceedings and transactions of the learned societies have been taken from the shelves and rearranged in more systematic order. These books have been consulted by members of the staff of the Institution as well as by others. In the reading room the additional shelving has allowed a better arrangement of the bound volumes of periodicals. Two thousand seven hundred and forty-seven periodicals were taken out for consultation. No additional libraries have been added to the list and those maintained in the Institution are the Secretary's library, Office library, and the Employee's library. The sectional libraries remain as before, i. e., Ærodromics, International Exchange, and Law Reference.

The sectional library of the Astrophysical Observatory was given a thorough overhauling and many volumes belonging to the Smithsonian deposit not being needed for use there were sent to the Library of Congress. As special help was provided, many of the missing parts of publications were noted and ordered, and at the close of the year most of these had been received. The number of volumes bound was 184.

The section of the library devoted to books of a popular nature for the use of the employees has been used more than ever. The success of the sending of a number of books to the Zoological Park once a month has more than repaid the trouble taken, and 575 books were sent out in the course of the year. There are now 1,413 volumes on the shelves of the library and 2,946 books were borrowed during the year; 100 magazines were bound and 43 new books added to the collection.

In the reading room, cataloguing room, and entry to the employees' library open shelving has been put up, in addition to that which was already in these places, giving room for expanding and for a better arrangement of the collections of books.

Gen. John Watts de Peyster has continued to add to his already large collection of books and pamphlets relating to Napoleon Bonaparte, and through his munificence many rare volumes have come to enrich the library of the Smithsonian Institution.

Besides these books, a collection of works on gypsies, a collection of dictionaries and encyclopedias, together with several portraits, pictures, and paintings are included in his gifts. Many of the dictionaries and encyclopedias are very rare and can not now be duplicated.

At the close of last year, the extension of the Parthenon frieze in the art room was under consideration, and during August and September very good casts of this frieze of about the right height were obtained and placed upon the walls.

The collection of books on art and kindred subjects now in the art room has received a valuable addition from Dr. E. A. Schwarz, who presented a number of art publications. It is hoped that in the near future time will be found for the card cataloguing of this collection, as well as many other works which are already there.

As Congress failed to appropriate money for the representation of the United States on the International Catalogue of Scientific Literature, the Smithsonian Institution again carried on the work, though with a sum quite insufficient for the needs and the necessary help. A larger amount has been allotted for the coming year, which will enable the Institution to do the work more thoroughly, and will also make it possible to fill in the gaps left in the reference to the literature of 1901. The following references were furnished to the central bureau:

Literature of 1901	6,150
Literature of 1902	8,330
Total	14,480

The subscription account of the catalogue within the United States is as follows:

Total number of subscriptions to complete sets	62
Total number of subscriptions to partial sets	37
Total	99

The following volumes of the International Catalogue of Scientific Literature of 1901 have been received and distributed: Botany, Part I; Chemistry, Part I; Mechanics; Physics, Part I; Meteorology; Physiology, Part I; Mathematics; Astronomy; Bacteriology; Physics, Part II; Mineralogy; Geology; Geography; and List of Journals.

The subscription price for these volumes represent a total of $3,926.82. Out of this sum $2,556.52 had been received up to June 30, 1903.

The United States National Museum library has been increased during the past year by two important gifts—the E. A. Schwarz collection of books, relating to American Coleoptera, and the W. H. Dall collection of books, bearing on recent and fossil mollusks. The Schwarz Library is one that was built up by Doctor Schwarz and G. G. Hubbard while carrying on their studies, and is intended to form an accessory to their collection of insects which was presented to the Museum some years ago.

Doctor Dall, as a collaborator in the Museum, has brought together, in connection with his studies on the collection of mollusks in the United States National Museum, a collection of books which comprises about 1,600 bound volumes and about 2,000 pamphlets. In connection with this library Doctor Dall also presents a card catalogue covering the literature of Conchology, recent and fossil, up to about 1860. He purchased from the executors of Mons. G. P. Deshayes, paleontologist, the original cards, numbering about 190,000. Doctor Dall obtained this catalogue some twenty-five years ago, and during the time it was in his possession he added materially to the number of cards relating to the genera of mollusks, though the series relating to species remains much as Monsieur Deshayes left it.

During the latter part of last summer the United States National Museum Library was closed to the public for the purpose of rearranging the books and sorting many into their proper place and series. This had been impossible during the last few

years, owing to the crowded condition; but within the past year the additional galleries provided have been turned over, thus giving the space needed for this purpose. All the shelves have been gone over, the books taken down and placed in the classification, making them more accessible, and a large number belonging to the Smithsonian deposit were separated from the Museum books and sent over to the Smithsonian Institution for checking preparatory to their being transmitted to the Library of Congress.

Three special collections of books in the library have been provided with book-plates—i. e., the Goode Library, the Schwarz Library, and the Dall Library.

The Museum library now contains 19,161 bound volumes and 32,063 unbound papers. The additions during the year consisted of 3,161 books, 3,260 pamphlets, and 303 parts of volumes. There were catalogued 916 books, of which 76 belonged to the Smithsonian deposit; 1,571 pamphlets, of which 18 belonged to the Smithsonian deposit, and 9,838 parts of periodicals, of which 2,274 belonged to the Smithsonian deposit.

Three thousand three hundred and sixteen cards were added to the Authors' Catalogue. These numbers do not include 4,614 cards for books and pamphlets recatalogued, and also do not include any of the books in the Dall library, but do include a number of those in the Schwarz library.

The number of books, pamphlets, and periodicals borrowed from the general library amounted to 23,583, including 4,833 withdrawn for assignment to the sectional libraries.

There has been no change in the sectional libraries established in the Museum, and they are as follows:

Administration.
Administrative assistant.
Anthropology.
Biology.
Birds.
Botany.
Children's room.
Comparative anatomy.
Editor.
Ethnology.
Fishes.
Geology.
History.
Insects.
Mammals.
Marine invertebrates.
Materia medica.
Mesozoic fossils.
Mineralogy.
Mollusks.
Oriental archæology.
Paleobotany.
Parasites.
Photography.
Prehistoric anthropology.
Reptiles.
Stratigraphic paleontology.
Superintendent.
Taxidermy.
Technology.

Respectfully submitted.

CYRUS ADLER, *Librarian.*

Mr. S. P. LANGLEY,

Secretary of the Smithsonian Institution.

Appendix VII.

REPORT OF THE EDITOR.

Sir: I have the honor to submit the following report on the publications of the Smithsonian Institution and its bureaus during the year ending June 30, 1902:

I. SMITHSONIAN CONTRIBUTIONS TO KNOWLEDGE.

1373. Hodgkins fund. The Structure of the Nucleus, a continuation of "Experiments in Ionized Air," by Carl Barus, Hazard professor of physics in Brown University, Providence, R. I. City of Washington: Published by the Smithsonian Institution, 1902. Quarto. Pages XIV, 176.

1413. [In press.] Hodgkins fund. On the Absorption and Emission of Air and its Ingredients of Wave Lengths from 250 $\mu\mu$ to 100 $\mu\mu$, by Victor Schumann. City of Washington: Published by the Smithsonian Institution, 1903. Quarto. Pages IV, 30, 4 plates.

The above memoirs complete Volume XXIX of Contributions to Knowledge, as follows:

Smithsonian Contributions to Knowledge. Vol. XXIX. City of Washington: Published by the Smithsonian Institution, 1903. Quarto.

CONTENTS.

Memoirs on Whalebone Whales of the Western Atlantic, by F. W. True, and on Comparison of the Features of the Earth and the Moon, by N. S. Shaler, were in final preparation for press at the close of the fiscal year.

II. MISCELLANEOUS COLLECTIONS.

A revised edition of Smithsonian Physical Tables, a list of publications by the Institution, and a pamphlet concerning the International Exchange Service, were issued in the series of Miscellaneous Collections. Several papers were in press at the close of the year.

1038. Smithsonian Physical Tables, prepared by Thomas Gray. Second Revised Edition. City of Washington: Published by the Smithsonian Institution, 1903. Octavo. Pages XXXIV, 301.

1372. The International Exchange Service of the Smithsonian Institution. Washington City: Published by the Smithsonian Institution, 1902. Octavo. Pages 4.

1376. List of Publications of the Smithsonian Institution 1846–1903. By William Jones Rhees, Washington City, 1903. Octavo. Pages VIII, 99.

1374. [In press.] Index to the Literature of Thorium, 1817–1902, by Cavalier H. Joüet, Ph. D. Octavo. About 130 pages.

1417. [In press.] Phylogeny of Fusus and its Allies, by Amadeus W. Grabau. Octavo. About 194 pages and 18 plates.

[——.] [In press.] A Select Bibliography of Chemistry, 1492–1902, by Henry Carrington Bolton. Second Supplement. Octavo. About 400 pages.

[——.] [In press.] Hodgkins fund. Researches on the Attainment of Very Low Temperatures, by Morris W. Travers. Octavo. About 30 pages.

III. SMITHSONIAN ANNUAL REPORTS.

The annual report is in two parts or volumes, one devoted to the Institution proper and the other to the National Museum. The contents of the Smithsonian volume for 1901 were given in the last report of the editor, though the bound volume had not then been received from the Public Printer. The 1902 volume has been put in type, though, with the exception of the Secretary's Report to the Regents, no parts had been distributed up to June 30, 1903. Additional copies of several papers from earlier reports were printed from the stereotype plates.

1367. Annual Report of the Board of Regents of the Smithsonian Institution, showing the operations, expenditures, and condition of the Institution for the year ending June 30, 1901. Washington: Government Printing Office, 1902. Octavo. Pages LXVII, 782, with 173 plates.

The contents of the 1902 Report are as follows:

1369. Report of S. P. Langley, Secretary of the Smithsonian Institution for the year ending June 30, 1902. From the Smithsonian Report for 1902, pages 1–115, with plates I–IX. Washington: Government Printing Office, 1903. Octavo. A small edition of this report in royal octavo form was printed in November, 1902.

1378. Journal of Proceedings of the Board of Regents of the Smithsonian Institution at meeting of January 22, 1902. Report of Executive Committee. Acts and Resolutions of Congress. From the Smithsonian Report for 1902, pages XI–LVI. Washington: Government Printing Office, 1901. Octavo.

1379. Recent Æronautical Progress, and Deductions to be drawn therefrom regarding the Future of Ærial Navigation. By Maj. B. F. S. Baden-Powell. From the Smithsonian Report for 1902, pages 121–131. Washington: Government Printing Office, 1903. Octavo.

1380. Some Æronautical Experiments. By Wilbur Wright. From the Smithsonian Report for 1902, pages 133–148 with plates I–IV. Washington: Government Printing Office, 1903. Octavo.

1381. Stellar Evolution in the Light of Recent Research. By Prof. George E. Hale. From the Smithsonian Report for 1902, pages 149–163, with plates I–XI. Washington: Government Printing Office, 1903. Octavo.

1382. A new Solar Theory. By Prof. J. Halm. From the Smithsonian Report for 1902, pages 165–176. Washington: Government Printing Office, 1903. Octavo.

1383. An Experimental Investigation of The Pressure of Light. By Peter Lebedew. From the Smithsonian Report for 1902, pages 177–178. Washington: Government Printing Office, 1903. Octavo.

1384. Comets' Tails, The Corona and the Aurora Borealis. By Prof. John Cox.

From the Smithsonian Report for 1902, pages 179–192. Washington: Government Printing Office, 1903. Octavo.

1385. "Good Seeing." By S. P. Langley. From the Smithsonian Report for 1902, pages 193–195, with plate I. Washington: Government Printing Office, 1903. Octavo.

1386. On the Radio-Activity of Matter. By Henri Becquerel, D. C. L., Ph. D. From the Smithsonian Report for 1902, pages 197–206, with plates I–VII. Washington: Government Printing Office, 1903. Octavo.

1387. History of Cold and the Absolute Zero. By Prof. James Dewar, M. A., LL. D., D. Sc., F. R. S. From the Smithsonian Report for 1902, pages 207–240. Washington: Government Printing Office, 1903. Octavo.

1388. Experimental Phonetics. By Prof. John G. McKendrick, F. R. S. From the Smithsonian Report for 1902, pages 241–259. Washington: Government Printing Office, 1903. Octavo.

1389. Wireless Telegraphy: Its Past and Present Status and its Prospects. By William Maver, jr. From the Smithsonian Report for 1902, pages 261–274, with plates I–IV. Washington: Government Printing Office, 1903. Octavo.

1390. Telpherage. By Charles M. Clark. From the Smithsonian Report for 1902, pages 275–286, with plates I–XIII. Washington: Government Printing Office, 1903. Octavo.

1391. The Evolution of Petrological Ideas. By J. J. Harris Teall, esq., M. A., V. P. R. S. From the Smithsonian Report for 1902, pages 287–308. Washington: Government Printing Office, 1903. Octavo.

1392. Preliminary Report on the Recent Eruptions of the Soufrière, in St. Vincent, and of a Visit to Mont Pelée, in Martinique. By Tempest Anderson, M. D., B. Sc., F. G. S., and John S. Flett, M. A., D. Sc., F. G. S. From the Smithsonian Report for 1902, pages 309–330, with plates I–III. Washington: Government Printing Office, 1903. Octavo.

1393. Volcanic Eruptions on Martinique and St. Vincent. By Israel C. Russell. From the Smithsonian Report for 1902, pages 331–349, with plates I–XI. Washington: Government Printing Office, 1903. Octavo.

1394. The Progress of Geographical Knowledge. By Col. Sir T. H. Holdich, C. B., K. C. I. E., F. R. G. S. From the Smithsonian Report for 1902, pages 351–373. Washington: Government Printing Office, 1903. Octavo.

1395. The Discovery of the Future. By H. G. Wells. From the Smithsonian Report for 1902, pages 375–392. Washington: Government Printing Office, 1903. Octavo.

1396. The Life of Matter. By A. Dastre. From the Smithsonian Report for 1902, pages 393–429. Washington: Government Printing Office, 1903. Octavo.

1397. The Craniology of Man and Anthropoid Apes. By N. C. Macnamara. From the Smithsonian Report for 1902, pages 431–449, with plates I–VI. Washington: Government Printing Office, 1903. Octavo.

1398. The Barroussé-Roussé Explorations: A Study of a New Human Type, by M. Verneau. By Albert Gaudry. From the Smithsonian Report for 1902, pages 451–453, with plates I, II. Washington: Government Printing Office, 1903. Octavo.

1399. Fossil Human Remains Found Near Lansing, Kansas. By W. H. Holmes. From the Smithsonian Report for 1902, pages 455–462, with plates I–III. Washington: Government Printing Office, 1903. Octavo.

1400. The Wild Tribes of the Malay Peninsula. By W. W. Skeat, M. A. From the Smithsonian Report for 1902, pages 463–478, with plates I, II. Washington: Government Printing Office, 1903. Octavo.

1401. The Pygmies of the Great Congo Forest. By Sir Harry H. Johnston, G. C. M. G. From the Smithsonian Report for 1902, pages 479–491. Washington: Government Printing Office, 1903. Octavo.

1402. Guam and Its People. By W. E. Safford. From the Smithsonian Report

for 1902, pages 493–508, with plates I–XII. Washington: Government Printing Office, 1903. Octavo.

1403. Oriental Elements of Culture in the Occident. By Dr. Georg Jacob. From the Smithsonian Report for 1902, pages 509–529. Washington: Government Printing Office, 1903. Octavo.

1404. The Nile Reservoir Dam at Assuan. By Thomas H. Means. From the Smithsonian Report for 1902, pages 531–535, with plates I–VI. Washington: Government Printing Office, 1903. Octavo.

1405. The Panama Route for a Ship Canal. By William H. Burr. From the Smithsonian Report for 1902, pages 537–557, with plates I, II. Washington: Government Printing Office, 1903. Octavo.

1406. The Problems of Heredity and Their Solution. By W. Bateson, M. A., F. R. S. From the Smithsonian Report for 1902, pages 559–580. Washington: Goverment Printing Office, 1903. Octavo.

1407. The Morphological Method and Recent Progress in Zoology. By Prof. G. B. Howes, D. Sc., LL. D., F. R. S. From the Smithsonian Report for 1902, pages 581–608. Washington: Government Printing Office, 1903. Octavo.

1408. Coral. By Dr. Louis Roule. From the Smithsonian Report for 1902, pages 609–612, with plates I, II. Washington: Government Printing Office, 1903. Octavo.

1409. Reindeer in Alaska. By Gilbert H. Grosvenor. From the Smithsonian Report for 1902, pages 613–623, with plates I–XI. Washington: Government Printing Office, 1903. Octavo.

1410. A Marine University. By W. K. Gregory. From the Smithsonian Report for 1902, pages 625–632, with plates I–III. Washington: Government Printing Office, 1903. Octavo.

1411. John Wesley Powell. By G. K. Gilbert. From the Smithsonian Report for 1902, pages 633–640, with plate I. Washington: Government Printing Office, 1903. Octavo.

1412. Rudolph Virchow, 1821–1902. By Oscar Israel. From the Smithsonian Report for 1902, pages 641–659, with plate I. Washington: Government Printing Office, 1903. Octavo.

IV. NATIONAL MUSEUM PUBLICATIONS.

The Museum volume of the Smithsonian Report for 1900 was distributed during the year and the volume for 1901 was in press. The contents of the 1900 volume were given in last year's report of the editor. The 1901 volume contains the Report on the Condition and Progress of the National Museum, by Richard Rathbun, Assistant Secretary of the Smithsonian Institution, and the following papers describing and illustrating collections in the Museum:

1. Report on the Exhibit of the United States National Museum at the Pan-American Exposition, Buffalo, N. Y., 1901, by Frederick W. True, William H. Holmes, and George P. Merrill.

2. Flint Implements and Fossil Remains from a Sulphur Spring at Afton, Ind. T., by William Henry Holmes.

3. Classification and Arrangement of the Exhibits of an Anthropological Museum, by William Henry Holmes.

4. Archæological Field Work in Northeastern Arizona. The Museum-Gates Expedition of 1901, by Walter Hough.

5. Narrative of a Visit to Indian Tribes of the Purús River, Brazil, by Joseph Beal Steere.

Volume XXIV of the Proceedings of the Museum was completed also the separates of volume XXV and most of those of volume XXVI:

Proceedings of the United States National Museum. Volume XXIV. Published under the direction of the Smithsonian Institution. Washington: Government Printing Office, 1902. Octavo, pages xv, 971, with 56 plates.

Papers from volume 25, proceedings of the U. S. National Museum.

No. 1275. A list of the beetles of the District of Columbia. By Henry Ulke Pages 1–57.

No. 1276. Some new South American birds. By Harry C. Oberholser. Pages 59–68.

No. 1277. The Casas Grandes meteorite. By Wirt Tassin. Pages 69–74, plates I–IV.

No. 1278. A review of the Oplegnathoid fishes of Japan. By David Starr Jordan and Henry W. Fowler. Pages 75–78.

No. 1279. Descriptions of two new species of Squaloid sharks from Japan. By David Starr Jordan and John Otterbein Snyder. Pages 79–81, figures 1, 2.

No. 1280. New diptera from North America. By D. W. Coquillett. Pages 83–126.

No. 1281. List of birds collected by William T. Foster in Paraguay. By Harry C. Oberholser. Pages 127–147.

No. 1282. The reptiles of the Huachuca Mountains, Arizona. By L. Stejneger. Pages 149–158.

No. 1283. Contributions toward a monograph of the lepidopterous family Noctuidæ of Boreal North America. A revision of the moths referred to the genus Leucania, with descriptions of new species. By John B. Smith. Pages 159–209, plates V–VI.

No. 1284. A list of spiders collected in Arizona by Messrs. Schwarz and Barber during the summer of 1901. By Nathan Banks. Pages 211–221, plate VII.

No. 1285. Observations on the crustacean fauna of the region about Mammoth Cave, Kentucky. By William Perry Hay. Pages 223–236, figure 1.

No. 1286. The Ocelot cats. By Edgar A. Mearns. Pages 237–249.

No. 1287. A review of the trigger-fishes, file-fishes and trunk-fishes of Japan. By David Starr Jordan and Henry W. Fowler. Pages 251–286, figures 1–6.

No. 1288. Birds collected by Dr. W. L. Abbott and Mr. C. B. Kloss in the Andaman and Nicobar islands. By Charles W. Richmond. Pages 287–314.

No. 1289. Notes on a collection of fishes from the island of Formosa. By David Starr Jordan and Barton Warren Evermann. Pages 315–368, figures 1–29.

No. 1290. Descriptions of the larvæ of some moths from Colorado. By Harrison G. Dyar. Pages 369–412.

No. 1291. A review of the cling-fishes (Gobiesocidæ) of the waters of Japan. By David Starr Jordan and Henry W. Fowler. Pages 413–416, figure 1.

No. 1292. Observations on the crustacean fauna of Nickajack Cave, Tennessee, and vicinity. By William Perry Hay. Pages 417–439, figures 1–8.

No. 1293. A review of the Blennoid fishes of Japan. By David Starr Jordan and John Otterbein Snyder. Pages 441–504, figures 1–28.

Nos. 1294 and 1295. A new fresh-water isopod of the genus Mancasellus from Indiana and a new terrestrial isopod of the genus Pseudarmadillo from Cuba. By Harriet Richardson. Pages 505–511, figures 1–4 and 1–4.

No. 1296. A review of the Chætodontidæ and related families of fishes found in the waters of Japan. By David Starr Jordan and Henry W. Fowler. Pages 513–563, figures 1–6.

No. 1297. The relationship and osteology of the Caproid fishes or Antigoniidæ. By Edwin Chapin Starks. Pages 565–572, figures 1–3.

No. 1298. Notes on little-known Japanese fishes, with description of a new species of Aboma. By David Starr Jordan and Henry W. Fowler. Pages 573–576, figure 1.

No. 1299. Cambrian Brachiopoda: Acrotreta; Linnarssonella; Obolus; with descriptions of new species. By Charles D. Walcott. Pages 577–612.

No. 1300. On certain species of fishes confused with Bryostemma polyactocephalum. By David Starr Jordan and John Otterbein Snyder. Pages 613–618, figures 1–3.

No. 1301. The shoulder girdle and characteristic osteology of the Hemibranchiate fishes. By Edwin Chapin Starks. Pages 619–634, figures 1–6.

No. 1302. North American parasitic copepods of the family Aguilidæ, with a bibliography of the group and a systematic review of all known species. By Charles Branch Wilson. Pages 635–742, plates VIII–XXVII, figures 1–23.

No. 1303. A review of the Ophidioid fishes of Japan. By David Starr Jordan and Henry W. Fowler. Pages 743–766, figures 1–6.

No. 1304. A revision of the American moths of the family Gelechiidæ, with descriptions of new species. By August Busck. Pages 767–938, plates XXVIII–XXXII.

No. 1305. A review of the dragonets (Callionymidæ) and related fishes of the waters of Japan. By David Starr Jordan and Henry W. Fowler. Pages 939–959, figures 1–9.

Papers from Volume 26, Proceedings of the U. S. National Museum.

No. 1306. A review of the Berycoid fishes of Japan. By David Starr Jordan and Henry W. Fowler. Pages 1–21, figures 1–4.

No. 1307. Japanese stalk-eyed crustaceans. By Mary Rathbun. Pages 23–55, figures 1–24.

No. 1308. A review of the Hemibranchiate fishes of Japan. By David Starr Jordan and Edwin Chapin Starks. Pages 57–73, figures 1–3.

No. 1309. Descriptions of new species of Hawaiian crabs. By Mary J. Rathbun. Pages 75–77, figures 1–3.

No. 1310. Contribution to a monograph of the insects of the order Thysanoptera inhabiting North America. By Warren Elmer Hinds. Pages 79–242, plates I–XI, text figures 1–127.

No. 1311. Description of a new genus and forty-six new species of crustaceans of the family Galatheidæ, with a list of the known marine species. By James E. Benedict. Pages 243–334, figures 1–47.

No. 1312. Synopsis of the family Veneridæ of the North American recent species. By William Healey Dall. Pages 335–412, plates XII–XVI.

No. 1313. On the lower Devonic and Ontaric formations of Maryland. By Charles Schuchert. Pages 413–424.

No. 1314. Observations on the number of young of the Lasiurine bats. By Marcus Ward Lyon, jr. Pages 425, 426, plate XVII.

No. 1315. Note on the sea anemone, Sagartia paguri Verrill. By J. Playfair McMurrich. Pages 427, 428, figures 1, 2.

No. 1316. On a small collection of crustaceans from the island of Cuba. By William Perry Hay. Pages 429–435, figures 1–3.

No. 1317. Mammals collected by Dr. W. L. Abbott on the coast and islands of Northwest Sumatra. By Gerrit S. Miller, jr. Pages 437–484, plates XVIII–XIX. Map.

No. 1318. Birds collected by Dr. W. L. Abbott on the coast and islands of Northwest Sumatra. By Charles W. Richmond. Pages 485–524. Map.

No. 1319. A review of the Synentognathous fishes of Japan. By David Starr Jordan and Edwin Chapin Starks. Pages 525–544, figures 1–3.

No. 1320. Notes on the osteology and relationship of the fossil birds of the genera Hesperornis, Hargeria, Baptornis, and Diatryma. By Frederic A. Lucas. Pages 545–556, figures 1–8.

No. 1321. Rediscovery of one of Holbrook's Salamanders. By Leonhard Stejneger. Pages 557, 558.

No. 1322. A new procelsterna from the Leeward Islands, Hawaiian group. By Walter K. Fisher. Pages 559–563.

No. 1323. The structural features of the bryozoan genus Homotrypa, with descriptions of species from the Cincinnatian group. By Ray S. Bassler. Pages 565–591, plates XX–XXV.

No. 1324. A review of the Elasmobranchiate fishes of Japan, By David Starr Jordan and Henry W. Fowler. Pages 593–674, plates XXVI–XXVII, figures 1–10.

No. 1325. The cerebral fissures of the Atlantic walrus. By Pierre A. Fish. Pages 675–688, plates XXVIII–XXIX.

No. 1326. Description of a new species of sculpin from Japan. By David Starr Jordan and Edwin Chapin Starks. Pages 689–690, figure 1.

No. 1327. On the identification of a species of eucalyptus from the Philippines. By Joseph Henry Maiden. Pages 691, 692.

No. 1328. Supplementary note on Bleekeria mitsukurii and on certain Japanese fishes. By David Starr Jordan. Pages 693–696, plate XXX, figures 1–3.

No. 1329. The use of the name torpedo for the electric catfish. By Theodore Gill. Pages 697,698.

No. 1330. A review of the Cepolidæ or band-fishes of Japan. By David Starr Jordan and Henry W. Fowler. Pages 699–702, figure 1.

No. 1331. A genealogic study of dragon-fly wing venation. By James G. Needham. Pages 703–764, plates XXXI–LIV, figures 1–44.

No. 1332. A review of the Cobitidæ or loaches of the rivers of Japan. By David Starr Jordan and Henry W. Fowler. Pages 765–774, figures 1, 2.

Of the bulletin series of Museum publications, Bulletin 52, Part II of Bulletin 50 and Part Q of Bulletin 39 were published.

Bulletin 52. A list of North American Lepidoptera and Key to the Literature of this order of insects. By Harrison G. Dyar, Ph. D., curator of Lepidoptera, U. S. National Museum, assisted by C. H. Fernald, Ph. D., the late George D. Hulst, and August Busck. Washington: Government Printing Office, 1902. Octavo. Pages XIX, 723.

Bulletin 50. The Birds of North and Middle America: A descriptive Catalogue of the Higher Groups, Genera, Species, and Subspecies of birds known to occur in North America, from the Arctic lands to the Isthmus of Panama, the West Indies, and other islands of the Caribbean Sea, and the Galapagos Archipelago. By Robert Ridgway, curator, Division of Birds. Part II. Family Tanagridæ—The Tanager. Family Icteridæ—The Troupials. Family Cœrebidæ—The Honey Creepers. Family Minotilidæ—The Wood Warblers. Washington: Government Printing Office, 1902. Octavo. Pages XX, 1–834, plates I–XXII.

Instructions to Collectors of Historical and Anthropological Specimens, by William Henry Holmes and Otis Tufton Mason, Part Q of Bulletin of the United States National Museum, No. 39. Washington: Government Printing Office, 1902. Octavo. Pages 16.

Additional copies of several publications of the Museum, of which the stock had become exhausted, were reprinted from the stereotype plates, including Volume I of Bulletin 47, on Fishes of North and Middle America, and papers by Stejneger on Poisonous Snakes, Ridgway on Humming Birds, and Dall's Catalogue of Shell-bearing Mollusks.

Of the series of contributions from the United States National Herbarium two former volumes, Nos. II and VII, were reprinted and parts 1, 2, and 3 of Volume VIII.

V. PUBLICATIONS OF THE ASTROPHYSICAL OBSERVATORY.

There was put to press toward the close of the year a report on The 1900 Solar Eclipse Expedition of the Astrophysical Observatory of the Smithsonian Institution, by S. P. Langley aided by C. G. Abbot. This is expected to make about 25 quarto pages of text with about 22 plates.

VI. PUBLICATIONS OF THE BUREAU OF AMERICAN ETHNOLOGY.

Nineteenth Annual Report of the Bureau of American Ethnology to the Secretary of the Smithsonian Institution, 1897–98. By J. W. Powell, Director. Parts I, II.

Washington: Government Printing Office, 1900. Large octavo. Pages I–XCII, 1–576*, 571–1160.

This report contains the following papers:

Part I.—Report of the Director, pages V–XCII. Myths of the Cherokees. By James Mooney, pages 3–548, plates I–XXVIII. Index. Pages 549–576*.

Part II.—Tusayan Migration Traditions. By Jesse Walter Fewkes, pages 573–634.

Localization of Tusayan clans. By Cosmos Mindeleff. Pages 635–653.

Mounds in Northern Honduras. By Thomas Gann. Pages 655–692, plates XXIX–XXXIX.

Mayan Calendar Systems. By Cyrus Thomas. Pages 693–819, plates XL–XLIV.

Primitive Numbers. By W J McGee. Pages 821–851.

Numerical Systems of Mexico and Central America. By Cyrus Thomas. Pages 853–955.

Tusayan Flute and Snake Ceremonies. By Jesse Walter Fewkes. Pages 957–1011, plates XLV–LXV.

The Wild Rice Gatherers of the Upper Lakes. By Albert Ernest Jenks. Pages 1013–1137, plates LXVI–LXXIX.

Index. Pages 1139–1160.

Bulletin 25. Natick Dictionary. By James Hammond Trumbull. Washington: Government Printing Office, 1903. Royal octavo, pages XXVIII, 349.

Bulletin 27. Tsimshian Texts. By Franz Boas. Washington: Government Printing Office, 1902. Royal octavo, pages 244.

VII. PUBLICATIONS OF AMERICAN HISTORICAL ASSOCIATION.

The Annual Report of the American Historical Association for the year 1902 was sent to the printer in April, but presswork was not completed before June 30. The report is in two volumes, pages 648, 527, with the following contents:

Volume I.

(392) Report of Proceedings of Eighteenth Annual Meeting, at Philadelphia, December 26–30, 1902, by Charles H. Haskins, corresponding secretary, pp. 17–45.

(393) Subordination in historical treatment, by Alfred Thayer Mahan, pp. 47–63.

(394) The Antecedents of the Declaration of Independence, by James Sullivan, with discussion by William A. Dunning, pp. 65–85.

(395) Studies in the History of the Federal Convention of 1787, by John Franklin Jameson, pp. 87–167.

(396) A Neglected Point of View in American Colonial History: The Colonies as Dependencies of Great Britain, by William MacDonald, pp. 169–178.

(397) The French Parliaments, by James Breck Perkins, pp. 179–190.

(398) The Art of Weaving: A Handmaid of Civilization, by William B. Weeden, pp. 191–210.

(399) Municipal Problems in Mediæval Switzerland, by John Martin Vincent, pp. 211–221.

(400) Party Politics in Indiana during the Civil War, by James Albert Woodburn, pp. 223–251.

(401) American Business Corporations before 1789, by Simeon E. Baldwin, pp. 253–274.

(402) The National Canal Policy, by Lindley M. Keasbey, pp. 275–288.

(403) The Neutralization Features of the Hay-Pauncefote Treaty, by John H. Latané, pp. 289–303.

(404) Suez and Panama, A Parallel, by Theodore S. Woolsey, pp. 305-311.

(405) Reasons for the Withdrawal of the French from Mexico, by Clyde Augustus Duniway, pp. 313–328.

(406) Report of the Public Archives Commission, by William MacDonald, Herbert L. Osgood, John Martin Vincent, Charles M. Andrews, Edwin Erle Sparks, pp. 329–363, including appendixes (Nos. 407, 408 below).

(407) The Archives of Oregon, by F. G. Young, pp. 337–355.

(408) Report on the Bexar Archives, by Eugene C. Barker, pp. 357–363.

(409) The Anti-Masonic Party, by Charles McCarthy, pp. 331–574.

(410) List of Publications of American Historical Association, with index of titles, by A. Howard Clark, pp. 575–639.

Volume II.

(411) Sixth Report of Historical Manuscripts Commission, by Edward G. Bourne, Frederick W. Moore, Theodore C. Smith, Reuben G. Thwaites, George P. Garrison, Worthington C. Ford. With diary and correspondence of Salmon P. Chase, as follows: Calendar of Chase letters heretofore printed and list of letters now printed; diary of S. P. Chase, July 21 to October 12, 1862; selected letters of Chase, 1846–1861; letters from George S. Denison to Chase, 1862–1865; miscellaneous letters to Chase, 1812–1870. pp. 1–527.

VIII. NATIONAL SOCIETY OF THE DAUGHTERS OF THE AMERICAN REVOLUTION.

The fifth report of the Society was received and submitted to Congress.

Respectfully submitted.

A. Howard Clark, *Editor.*

Mr. S. P. Langley,
Secretary of the Smithsonian Institution.

August 1, 1903.

GENERAL APPENDIX

TO THE

SMITHSONIAN REPORT FOR 1903.

ADVERTISEMENT.

The object of the GENERAL APPENDIX to the Annual Report of the Smithsonian Institution is to furnish brief accounts of scientific discovery in particular directions; reports of investigations made by collaborators of the Institution; and memoirs of a general character or on special topics that are of interest or value to the numerous correspondents of the Institution.

It has been a prominent object of the Board of Regents of the Smithsonian Institution, from a very early date, to enrich the annual report required of them by law with memoirs illustrating the more remarkable and important developments in physical and biological discovery, as well as showing the general character of the operations of the Institution; and this purpose has, during the greater part of its history, been carried out largely by the publication of such papers as would possess an interest to all attracted by scientific progress.

In 1880 the Secretary, induced in part by the discontinuance of an annual summary of progress which for thirty years previous had been issued by well-known private publishing firms, had prepared by competent collaborators a series of abstracts, showing concisely the prominent features of recent scientific progress in astronomy, geology, meteorology, physics, chemistry, mineralogy, botany, zoology, and anthropology. This latter plan was continued, though not altogether satisfactorily, down to and including the year 1888.

In the report for 1889 a return was made to the earlier method of presenting a miscellaneous selection of papers (some of them original) embracing a considerable range of scientific investigation and discussion. This method has been continued in the present report for 1903.

GENERAL DESCRIPTION OF THE MOON.[a]

By N. S. Shaler,
Professor, Harvard University.

Although the moon has been the most studied of all celestial objects, few persons except astronomers have a clear idea of even the general results which have been derived from the vast body of observations that have been made upon it. For this reason it appears desirable to preface the account of the special inquiries which are set forth in the following pages by a statement of what is known concerning this nearest neighbor of our earth. This account will necessarily be limited to the facts which can be set forth in other than mathematical form; fortunately these include all that the reader needs to have in mind in order to obtain a fairly clear understanding of the questions which are to be discussed.

The history of primitive astronomy shows that the moon, of all celestial objects, from the beginning of man's intellectual development has been the most closely observed. Although the sun was doubtless recognized by the lowliest man as the most important feature of the heavens, as the giver of life, the conditions under which it is seen, especially its blinding light, long made any extended study of it impossible. So, except for the very evident changes of its course across the sky and the consequent succession of the seasons, little was known of the solar center two hundred years ago, and, save its approximate distance from the earth, its mass, and its general relations to the planets, not much knowledge of it was gained until the last century. On the other hand, the moon, because of its nearness, being only about one four-hundredth part as remote from the earth as the sun, has in a noteworthy way entered into the records of men. Its relatively short period of change and the very pronounced character of its alterations made it the first index of time beyond the round of the day. It is evident, indeed, that as soon as men began to reckon time they used the lunar month to make their tally, rather than that of the solar year.

[a] Introductory chapter from A Comparison of the Features of the Earth and the Moon, by Prof. N. S. Shaler, Smithsonian Contributions to Knowledge, Vol. XXXIV (No. 1438), 1903. Quarto, pp. 78, with 25 plates.

Moreover, the surface of the moon reveals much to the naked eye, not clearly, but sufficiently well to afford the basis for speculation and to tempt the imagination to create there a world like our own. It is therefore not surprising that a host of myths concerning the nature of our satellite grew up in the days before the telescope. It is interesting to note the fact that many of these myths have not only become fixed in the minds of uninstructed people, but they have had a remarkable influence upon modern astronomers, limiting their capacity to interpret what their instruments clearly reveal to them. At every stage in the advance of selenography we note the curious persistency of the endeavor not only to interpret the lunar features by the terrestrial, but to warp the observed facts into accord with those seen on the earth. There is perhaps no better instance of the extent to which prepossessions and prejudices may affect the judgment of the most conscientious observer, blinding him to evident truth, than the history of lunar inquiries affords.

The story of the physical conditions of the moon had best be begun by noting that the relation of our satellite to a larger sphere is not exceptional, but the most characteristic of all the relations of one stellar body to another. Of the planets in the solar system, all save the two nearest to the sun, Mercury and Venus, have one or more smaller spheres circling about them. The relation of the sun to the several planets in a larger way repeats this plan of grouping lesser about greater orbs.

It is generally believed by astronomers that the celestial spheres have been formed by a process of condensation, due to gravitation, of matter which was originally widely diffused; that our solar system, before it was organized into the sun and lesser bodies, was in the form of a diffused nebulous mass of spheroidal form which extended beyond the orbit of the outermost planet. As this matter gathered toward the center, the material now in each of the planets and its satellites parted from the parent body, probably at first in the form of a nebulous ring, or spiral, which in time broke and gathered into a spheroidal mass. In that detached portion of the parent nebula the process of concentration was repeated, with the result that satellites, or, as we may term them, secondary planets, were formed substantially as the greater spheres were set off from the sun. There are many questions and doubts concerning the details of this nebular theory, but that the evolution of our solar system, and probably of all stellar systems, took place in substantially the manner indicated appears to be eminently probable; it is, indeed, fairly well established by what we know of the distant nebulæ and by the rings of Saturn, which apparently contain the material which normally should have formed one or more of its satellites, but which for some unknown reason have remained unbroken.

It is not certain at just what stage in the concentration of a nebula, a planet or a satellite may be set off from the parent body; nor can the present distance of the satellite from the main sphere be assumed as that at which the parting took place. It is possible that the concentration of the parent body had gone so far that the diffused or nebulous stage of its materials had been passed by and the more advanced stage of igneous fluidity entered on. It is, however, more likely that in all cases the separation occurred while the particles of matter were divided as they are in a gas or vapor. As soon as the two spheres are separated from one another, and so long as they remain in any measure fluid, the difference in their gravitative attraction on the nearer and more remote part of their masses induces tides, and the effect of these tidal movements, as has been shown by Prof. George Darwin, is necessarily to impel the two bodies farther apart. It seems certain that before the earth and the moon became essentially rigid, as they now are, the effect of these tides in driving them apart must have been great enough to account for a considerable part of the interval which now separates them.

In the present condition of the moon it is a sphere having a computed diameter of 2,159.6 miles and its mean distance from the earth 238,818 miles. So far as has been determined the moon exhibits no trace of flattening at the poles, such as characterizes the earth, unless, as is possible, there are irregularities of figure on the unseen part of the sphere. It is essentially globular in form. The fact that the moon is not flattened at its poles probably indicates that if it once rotated in the manner of the planet it ceased to do so before it became solid.

The measure of density of the moon—i. e., the proportion of its weight to its bulk—is only about six-tenths that of the earth. While the earth's mean density is nearly 5.7 times that of water, that of the moon is about 3.5 times as great. Thus the total gravitative force of the lunar mass is to be reckoned as only about one eighty-first of that of our planet.

As the moon revolves on its polar axis but once in about a month, and at a rate that tends to keep the same part of its surface turned toward the earth, we should, but for the phenomenon of librations, see no more than one-half of its superficial area. Owing, however, to this feature, which is due to certain complications of the moon's exceedingly varied movements, the satellite in effect sways in relation to the earth so that at certain times we see farther to the east and at others farther to the west of its center, and in the succession of these movements we are able to behold somewhat more than one-half the total area—in fact, about six-tenths of it. It is impossible to set forth in this writing the reasons for the librations of the moon, as the matter can not be explained without giving in mathematical form a full

account of the motion of our satellite, which is one of the most complicated of astronomical problems.[a]

As noted below, there is some accessible information going to show that even beyond the extreme field revealed by the librations the surface of the moon has the same character as that which is visible. Thus we find that up to the limits of the visible part there is no sign of change in the nature of the surface. It is therefore reasonable to conclude that the same characteristics extend for some distance beyond the limits of vision. We also note on the verge of the unseen field the hither margins of certain ring-shaped structures, the so-called volcanoes, evidently of large size, so that it is fair to conclude that these features are continued on the unseen part. Moreover, there are some light-colored bands, such as on this side of the moon always radiate from crater-like pits, which apparently come over from such centers on the unseen part. These several facts, taken together, make it eminently probable that the unseen four-tenths of the lunar surface in no essential way differs from that we observe. It is, indeed, altogether likely that we see every type of structure that exists on the moon, and that a view of its whole area would add nothing essentially new to our knowledge of the sphere.

Seen by persons of ordinarily good vision, even at a distance of about 240,000 miles, the moon reveals much of its surface shape, structure, and color; it is evident that the color varies greatly from very bright areas to those which are relatively dark, that the latter are somewhat less in total extent than the former, and that they are disposed in a general way across the northern hemisphere.[b] Persons of more than usually good vision may, under favorable conditions, see on the edge of the illuminated area the ragged line of the sunlight, which indicates that the surface is very irregular, the high points coming into the day before the lower are illuminated. Such persons at time of full moon can also note, though faintly, some of the bright bands which, radiating from certain crater-like pits, extend for great distances over the surface. So, too, they may see at the first stage of the new and the last of the old moon, the light from the sunlit earth slightly illuminating the dark part of the lunar sphere, or, as it is often termed, the old moon in the arms of the new.

With the best modern telescopes under the most suitable conditions of observation the moon is seen as it would be by the unaided eye if

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[a] An excellent nonmathematical presentation of the question, which affords a sufficient idea of it, may be found in The Moon, by Richard A. Proctor, pp. 117 et seq., D. Appleton & Co., New York, 1878.

[b] It is well to note the fact that in a celestial telescope objects are seen in reverse position, or "upside down." For convenience they are usually so depicted on maps and pictures of the moon; the north pole at the bottom, and the east where it is customary to place the west on terrestrial maps.

it were not more than about 40 miles from the observer. The conditions of this seeing are much more favorable than those under which we behold a range of terrestrial mountains at that distance, for the reason that the air, and especially the moisture, in our atmosphere hinders and confuses the light, and there is several times as much of this obstruction encountered in a distance of 40 miles along the earth's surface as there is in looking vertically upward.

Seen with the greater telescopes, the surface of the moon may reveal to able observers, in the rare moments of the best seeing, circular objects, such as pits, which are perhaps not more than 500 feet in diameter. Elevations of much less height may be detected by their shadows, which, because there is no trace of an atmosphere on the moon, are extraordinarily sharp, the line between the dark and light being as distinct as though drawn by a ruler. Elongate objects, such as rifts or crevices in the surface, because of their length, may be visible even when they are only a few score feet in width, for the same reason that while a black dot on a wall may not make any impression on the eye, a line no wider than the dot can be readily perceived. Owing to these conditions, the surface of the moon has revealed many of its features to us, perhaps about as well as we could discern them by the naked eye if the sphere were no more than 20 miles away.

Separated from all theories and prepossessions, the most important points which have been ascertained as to the condition of the moon's surface are as follows:

The surface differs from that of the earth in the fact that it lacks the envelopes of air and water. That there is no air is indicated by the feature above noted—that there is no diffusion of the sunlight, the shadows being absolutely black and with perfectly clean-cut edges. It is also shown by the fact that when a star is occulted or shut out by the disc of the moon it disappears suddenly without its light being displaced, as it would be by refraction if there were any sensible amount of air in the line of its rays. This evidence affords proof that if there is any air at all on the moon's surface it is probably less in amount than remains in the nearest approach to a vacuum we can produce by means of an air pump. Like proof of the airless nature of the moon is afforded by the spectroscope applied to the study of the light of an occulting star or that of the sun as it is becoming eclipsed by the moon. In fact, a great body of evidence goes to show that there is no air whatever on the lunar surface.

The evidence of lack of water at the present time on the surface of the moon appears to be as complete as that which shows the lack of an atmosphere. In the first place, there are evidently no seas or even lakes of discernible size. There are clearly no rivers. If such features existed, the reflection of the sun from their surfaces would make

them exceedingly conspicuous on the dark background of the moon, which for all its apparent brightness is really as dark as the more somber-hued rocks of the earth's surface when lit by the sun. Moreover, even were water present, without an atmosphere there could be no such circulation as takes place on the earth, upward to clouds and thence downward by the rain and streams to the ocean. Clouds can not exist unless there be an atmosphere in which they can float, and even if there be an air of exceeding tenuity on the moon, it is surely insufficient to support a trace of clouds. Some distinguished astronomers have thought to discern something floating of a cloud-like nature, but these observations, though exceedingly interesting, are not sufficiently verified to have much weight against the body of well-observed facts that shows the moon to be essentially waterless.

The well-established absence of both air and water in any such quantities as is necessary to maintain organic life appears to exclude the possibility of there being any such life as that of plants and animals on the lunar surface. It may be stated that very few astronomers are now inclined to believe that the moon can possibly be the abode of living forms.

Being without an effective atmosphere, for the possible but unproved remnant that may exist there would be quite ineffective, the moon lacks the defense against radiation of heat which the air affords the earth. Therefore in the long lunar night the outflow of heat must bring the temperature of the darkened part to near that of the celestial spaces, certainly to some hundred degrees below Fahrenheit zero. Even in the long day this lack of air and consequent easy radiation must prevent any considerable warming of the surface. The temperature of the moon has been made the matter of numerous experiments. These, for various reasons, have not proved very effective. The most trustworthy, the series undertaken by S. P. Langley, indicate that at no time does the heat attain to that of melting ice.

Turning now to the shape and structure of the moon's crust, we observe that it differs much from that of the earth. Considering first the more general features, we note that there are none of those broad ridges and furrows—the continents and the sea basins. A portion of the surface, mainly in the northern hemisphere, is occupied by wide plains, which in their general shape are more nearly level than any equally extensive areas of the land, or, so far as we know, of the ocean floor of the earth, though they are beset with very many slight irregularities. These areas of rough, dark-hued plains are the seas or maria of selenographers, so termed because of old they were, from their relatively level nature, supposed to be areas of water. These maria occupy about one-third of the visible surface. Their height is somewhat less than that of the crust outside of their area. The remaining portion of

the moon is extremely rugged. It is evident that the average declivity of the slopes is far greater than on the earth. This is apparent in all the features made visible by the telescope, and it likely extends to others too minute to be seen by the most powerful instruments. Zöllner, by a very ingenious computation based on the amount of sunlight reflected, estimates that the average angle of the lunar surface to its horizon is 52 degrees. Though we have no such basis for reckoning the average slope of the lands and sea bottoms of the earth, it is eminently probable that it does not amount to more than a tenth of that declivity. This difference, as well as many others, is probably due to the lack on the moon of the work of water, which so effectively breaks down the steeps of the earth, tending ever to bring the surface to a uniform level.

The most notable feature on the lunar surface is the existence of exceedingly numerous pits, generally with ring-like walls about them, which slope very steeply to a central cavity and more gently toward the surrounding country. These pits vary greatly in size; the largest are more than a hundred miles in diameter, while the smallest discernible are less than a half mile across. The number increases as the size diminishes; there are many thousands of them, so small that they are revealed only when sought for with the most powerful telescopes and with the best seeing. In all these pits, except those of the smallest size, and possibly in these also, there is within the ring wall and at a considerable though variable depth below its summit a nearly flat floor, which often has a central pit of small size or in its place a steep, rude cone. When this plain is more than 20 miles in diameter, and with increasing numbers as the floor is wider, there are generally other irregularly scattered pits and cones. Thus in the case of Plato, a ring about 60 miles in diameter, there are some scores of these lesser pits. On the interior of the ring walls of the pits over 10 miles in diameter there are usually more or less distinct terraces, which suggest, if they do not clearly indicate, that the material now forming the solid floors they inclose was once fluid and stood at greater heights in the pit than that at which it became permanently frozen. It is, indeed, tolerably certain that the last movement of this material of the floors was one of interrupted subsidence from an originally greater elevation on the outside of the ring wall, which is commonly of irregular height, with many peaks. There are sometimes tongues or protrusions of the substance which forms the ring, as if it had flowed a short distance and then had cooled with steep slopes.

The foregoing account of the pits on the lunar surface suggests to the reader that these features are volcanoes. That view of their nature was taken by the astronomers who first saw them with the telescope and has been generally held by their successors. That they are in

some way, and rather nearly, related to the volcanic vents of the earth appears certain. We have now to note the following peculiar conditions of these pits. First, that they exist in varying proportion, with no evident law of distribution, all over the visible area of the moon. Next, that in many instances they intersect each other, showing that they were not all formed at the same time, but in succession; that the larger of them are not found on the maria, but on the upland and apparently the older parts of the surface; and that the evidence from the intersections clearly shows that the greater of these structures are prevailingly the elder and that in general the smallest were the latest formed. In other words, whatever was the nature of the action involved in the production of these curious structures, its energy diminished with time, until in the end it could no longer break the crust.

All over the surface of the moon, outside of the maria, in the regions not occupied by the volcano-like structures, we find an exceedingly irregular surface, consisting usually of rude exerescences with no distinct arrangement, which may attain the height of many thousand feet. These, when large, have been termed mountains, though they are very unlike any on the earth in their lack of the features due to erosion, as well as in the general absence of order in their association. Elevations of this steep, lumpy form are common on all parts of the moon. Outside of the maria they are seen at their best in the region near the north pole, where a large field thus beset is termed the Alps. From the largest of these elevations a series of like forms can be made of smaller and smaller size until they become too minute to be revealed by the telescope; as they decrease in height they tend to become more regular in shape, very often taking on a dome-like aspect. The only terrestrial elevations at all resembling these lunar reliefs are certain rarely occurring masses of trachytic lava, which appear to have been spewed out through crevices in a semifluid state, and to have been so rapidly hardened in cooling that the slopes of the solidified rock remained very steep. The only reliefs on the moon that remind the geologist of true mountains are certain low ridges on the surfaces of the maria.

The surface of the moon exhibits a very great number of fissures or rents which, when widely opened, are termed valleys, and when narrow, rills. Both these names were given because these grooves were supposed to have been the result of erosion due to flowing water. The valleys are frequently broad, in the case of that known as the "Alpine Valley," at certain places several miles in width; they are steep walled, and sometimes a mile or more in depth; their bottoms, when distinctly visible, are seen to be beset with crater-like pits, and show in no instance a trace of water work, which necessarily excavates

smooth descending floors such as we find in terrestrial valleys. The rills are narrow crevices, often so narrow that their bottoms can not be seen; they frequently branch, and in some instances are continued as branching cracks for 100 miles or more. The characteristic rills are far more abundant than the valleys, there being many scores already described; the slighter are evidently the more numerous; a catalogue of those visible in the best telescopes would probably amount to several thousand. (See plates VI, IX, X.)

It is a noteworthy fact that in the case of the rills, and in great measure also in the valleys, the two sides of the fissure correspond so that if brought together the rent would be closed. This indicates that they are essentially cracks which have opened by their walls drawing apart. Curiously enough, as compared with rents in the earth's crust, there is little trace of a change of level of the two sides of these rills—only in one instance is there such a displacement well made out, that known as the Straight Wall, where one side of the break is several hundred feet above the other. (See plate IX.)

In the region outside of the maria much of the general surface of the moon between the numerous crater-like openings appears in the best seeing with powerful telescopes to be beset with minute pits, often so close together that their limits are so far confused that it appears as honeycombed, or, rather, as a mass of furnace slag full of holes if greatly magnified, through which the gases developed in melting the mass escaped. (See plate V.)

Perhaps the most exceptional feature of the lunar surface, as compared with that of the earth, is found in the numerous systems of radiating light bands, in all about thirty in number, which diverge from patches of the same hue about certain of the crater-like pits. These bands of light-colored material are generally narrow, not more than a few miles in width; they extend for great distances, certain of them being over 1,000 miles in length, one of them attaining to 1,700 miles in linear extent. In one instance at least, in the crater named Saussure, a band which intersects the pit may be seen crossing its floor, and less distinctly, yet clearly enough, it appears on the steep inside walls of the cavity. In no well-observed case do these radiating streaks of light-colored material coincide with the before-mentioned splits or rifts. Yet the assemblage of facts, though the observations and the theories based upon them are very discrepant, lead us to believe that they are in the nature of stains or sheets of matter on the surface of the sphere, or perhaps in the mass of the crust. At some points the rays of one system cross those of another in a manner that indicates that the one is of later formation than the other. (See plates III, VII, VIII.)

Perhaps the most puzzling feature of the radiating streaks, where everything is perplexing, is found in the way they come into view and disappear in each lunar period. When the surface is illuminated by the very oblique rays of the sun they are quite invisible; as the lunar day advances they become faintly discernible, but are only seen in perfect clearness near the full moon. The reason for this peculiar appearance of these light bands under a high sun has been a matter of much conjecture; it is the subject of discussion in a later chapter of this memoir, where it is shown that inasmuch as these bands appear when the earth light falls upon the moon at a high angle, the effect must be due to the angle of incidence of the rays on the shining surfaces. It should be noted that the light bands in most instances diverge from more or less broad fields of light color about the crater-like pits, fields which have the same habit of glowing under a high illumination; in fact, a large part of the surface of the moon, perhaps near one-tenth of its visible area, becomes thus relatively brilliant at full moon, though it lacks that quality at the earlier and later stages of the lunar day.

In the above-considered statement concerning the visible phenomena of the moon no account is taken of a great variety of obscure features which, though easily seen with fairly good instruments, have received slight attention from selenographers. As can readily be imagined, observers find it difficult to discern dimly seen features which can not be classed in any group of terrestrial objects. Whosoever will narrowly inspect any part of the lunar surface, noting everything that meets his eye, will find that he observes much that can not be explained by what is seen on the earth. It is evident, indeed, that while in the earlier stages of development this satellite in good part followed the series of changes undergone by its planet there came a stage in which it ceased to continue the process of evolution that the parent body has undergone. The reason for this arrest in development appears to have been the essential if not complete absence of an atmosphere and of water.

The difference in height between the lowest and highest points on the lunar surface is not determined. To the most accented reliefs, those of the higher crater walls, elevations of more than 25,000 feet have been assigned; it is, however, to be noted that all these determinations are made from the length of the shadows cast by the eminences, with no effective means of correcting for certain errors incidental to this method. It may be assumed as tolerably certain that a number of these elevations have their summits at least 20,000 feet above their bases, and that a few are yet higher. We do not know how much lower than the ground about these elevations are the lowest parts of the moon. My own observations incline me to the

opinion that the difference may well amount to as much as 10,000 feet, so that the total relief of the moon may amount to somewhere between 30,000 and 40,000 feet. That of the earth from the deepest part of the oceans to the highest mountain summits is probably between 55,000 and 60,000 feet; so that notwithstanding the lack of erosion and sedimentation which in the earth continually tends to diminish the difference between the sea-floor and land areas, the surface of the satellite has a much less range of elevation than the planet. If the forces which have built the mountains and continents of the earth had operated without the erosive action of water, there is little doubt that the difference in height between the highest and lowest parts would now be many times as great as it is on the moon.

[The following are ten plates selected from the 25 plates in the full memoir.]

PLATE I.

Age of moon, 8 days 4 hours. September 22, 1890. Lick Observatory.

[In accordance with the usage of selenographers, the plates are printed in the reversed order in which they appear in a celestial telescope. The top of each is the south, the bottom the north, the right-hand the east, and the left the west.]

In Pl. I the most noteworthy features are the maria of the western half of the visible portion of the sphere. The rudely circular form of these fields is well shown, also the fact that none of them extend to the margin or "limb" of the moon. The bright, slightly curved ridge in the lower half of the picture facing the partly illuminated mare—the Mare Imbrium—is the Apennines; the large vulcanoid at its southern end is Eratosthenes. The larger pit in the ocean opposite the center of the range is Archimedes; the two craters next to the north are, the nearer, Autolycus, and the farther and larger, Aristillus. The larger of the two dark pits near the northern end of the Apennines is Eudoxus, the smaller, Aristoteles. Southeast from these craters lie the Alps, a group of bright peaks extending in a northeast and southwest direction. A faint, dark streak shows the position of the Alpine Valley. The flat, irregular area north of the range is the M. Frigoris.

Close inspection of this plate will show that many of the vulcanoids[a] have pits or cones on their floors, and that these are very often in the center of these level spaces.

The radiating bands or streaks are beginning to appear.

In the Mare Imbrium, near the western end of the Alps, next north of Aristillus, is Cassini, of which the encircling cone appears to have been partly melted down by the lava of the mare so that it shows as a faint ridge with a distinct central crater.

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[a] In this memoir all the features of the moon commonly termed "volcanoes" etc., are designated by the generic term "vulcanoid."

AGE OF MOON, 8 DAYS 4 HOURS. SEPTEMBER 22, 1890. LICK OBSERVATORY.

MOON'S AGE, 10 DAYS 12 HOURS. LICK OBSERVATORY, 1890.

PLATE II.

Moon's age, 10 days 12 hours. Lick Observatory, 1890.

The most noteworthy changes as compared with Pl. I are the great advance in the development of the fields of very bright hue, and in the bands radiating from them. These are most evident in the system of Copernicus. The system of Tycho also begins to be evident. This vulcanoid may be identified as the deep large crater with a central cone near the border of the illuminated area. The general irregularity of these light bands is well shown in those about Copernicus. So, too, the fact that they are projections from an illuminated or lucent field about the vulcanoid.

The relative absence of large vulcanoids on the maria is noteworthy. Those which exist lie nearly, if not altogether, on fields of high ground which appear to have risen above the floors of the maria and so escaped melting.

The problematical crater Linné now appears as a small white patch near the middle of the eastern side of the M. Serenitatis.

PLATE III.

Moon's age, 14 days 1 hour. July 19, 1891. Lick Observatory.

In this plate the moon is nearly full, the light being oblique enough to illuminate the crater walls on the eastern margin alone.

The maria are well shown nearly to the eastern margin. Separated by a belt of relatively high ground from the Oceanus Procellarum is the large vulcanoid Grimaldi. It has a small crater on its floor near its northern side. This vulcanoid has a floor nearly as dark as the seas. It will be noted that Plato has also a dark floor. On the margin of the Oceanus Procellarum, southwest of Grimaldi, is a crater Letronne rather indistinctly seen, the wall of which that faces the maria is, as in other instances, ruined apparently by the lava of the sea. Other like examples are shown in this neighborhood. On the shores of the M. Humorum there are three similar instances of crater walls broken down on the seaward side.

It should be noted that none of the maria distinctly attain the margin of the moon's surface. On the eastern lands the O. Procellarum comes near to the border of the moon, but high, rugged land is obscurely visible on the very edge. This is more clearly disclosed at certain stages of libration. On the southwest border some observers think there is a nearly level area crossing the border, but, as will be seen, the level land there has not the characteristic dark hue of the maria.

It will be observed that in this nearly vertical light, except Plato, the craters on the eastern margin only are distinctly visible. Those exceptions are due to the dark color of their floors. There are two or three craters near the south pole which, because they have rather dark bottoms, are faintly seen.

MOON'S AGE, 14 DAYS 1 HOUR. JULY 19, 1891, LICK OBSERVATORY.

MOON'S AGE, 23 DAYS 7 HOURS. JULY 28, 1891, LICK OBSERVATORY.

PLATE IV.

Moon's age, 23 days 7 hours. July 28, 1891. Lick Observatory.

At this stage of the waning moon the most interesting of its fields are no longer visible. There are few that command attention in this plate. It may be noted that the system of light bands and the central patches whence they proceed, that have their center in Kepler, are still very bright. The dark mare-like floor of Grimaldi is visible near the bright margin of the sphere. The observer may obtain something of the impression, such as is afforded by good seeing with a powerful telescope, that the Oceanus Procellarum is a relatively shallow sea by the number of fragments of what seems to have been the more ancient surface that protrude through it.

PLATE V.

Moon's age, 21 days 16 hours. 1895.

In this plate is depicted an area from near the moon's equator to near the south pole. On the eastern margin the sunlight is passing from the surface, the evening light being so oblique that the bottoms of the vulcanoids are more or less in shadow. Here and there, in the advancing night, there are lofty peaks on the margin of crater rims, which still receive a touch of sun and appear as bright points in a black field. On the western margin the surface is still well illuminated, with the consequent effect that the surface appears to be much smoother than it is. A view taken a few hours later would show about as rude a margin as is here depicted.

Perhaps more effectively than any other this view shows how the general surface of the moon outside of the maria is essentially made up of vulcanoids and ridges, the apparently smooth parts appearing so only because the small irregularities are not visible. In this connection it should be noted that near the dark part the surface is seen to be beset by small shallow craters, the smallest visible being more than a mile in diameter and probably several hundred feet deep. Such pits, in equal numbers to the unit of surface, exist on the bright part to the left when they are observed by the higher light.

The way in which the smaller craters cut the larger is shown at many points in this field of view; so, too, the relative lack of sharpness of outline of the greater vulcanoids as compared with the lesser objects of this group. The low, narrow ridges which surround the pits are insufficiently shown because the light does not bring them out. They are best observed near the uppermost part of the picture.

The generality of the fact that the larger craters have flat floors and that these floors are prevailingly nearly level is well indicated; so, too, the fact that there is a common tendency of these floors to have either a small crater or a cone in or near the center of each circular field. Four such craters in the central part of the area extending in an obscure line from near the base to near the middle of the picture have cones in their centers. In all, about a dozen of the hundred or so instances in which they would be recognizable have this feature. It will be evident that all the craters in this region have their floors far below the level of the encircling ring and below the general lunar surface.

In sundry instances two adjacent vulcanoids of moderate size have their neighboring walls broken down so that they exhibit the first stage of "crater valleys," with a general north and south axis. There are in all about ten cases of this kind on this field, but several of them are not well disclosed by this illumination.

MOON'S AGE, 21 DAYS 16 HOURS. 1895.

PHOTOGRAPHED BY RITCHEY WITH 40-INCH TELESCOPE, USING YELLOW COLOR SCREEN AND ISOCHROMATIC PLATE.

PLATE VI.

Photographed by Ritchey with 40-inch telescope, using yellow color screen and isochromatic plate.

This plate shows part of the southwest quarter of the moon's visible surface.

On the lower part of the plate is a portion of the Mare Tranquilitatis; on the middle of the left-hand side a portion of the Mare Nectaris.

The large, deep vulcanoid with the steep, ragged peaks rising from its floor, on the lower left-hand portion of the plate, is Theophilus, one of the noblest structures on the moon. The width of the crater is about 64 miles; the greatest height from the floor to the crest of the wall, 18,000 feet. The central mass, composed of several sharp peaks, rises about 6,000 feet above the lava plain. In the center of these masses there appears to be an obscure crater about half a mile in diameter. The terraces in the inner wall of the cone are indistinctly shown.

Theophilus has partly invaded Cyrillus, the next large vulcanoid on the southeast, an older structure with less steep slopes and a generally ruined appearance. South of Cyrillus, at a distance of half its width, is Catherina. This crater is met by another of half its diameter, which has developed on one side of its floor. From near the southeastern margin of Catherina a beautiful row of small craters extends eastwardly for a distance of over 200 miles to the large vulcanoid Abulfeda. This is perhaps the most noteworthy crater row on the moon.

The long, curved wall extending from Piccolomini, near the upper left-hand corner (the large crater with its floor in shadow), to the east side of Catherina, is the Altai Mountains. It should be noted that this step-like structure obscurely extends northward to the M. Tranquilitatis, where it forms an irregular ridge-like promontory.

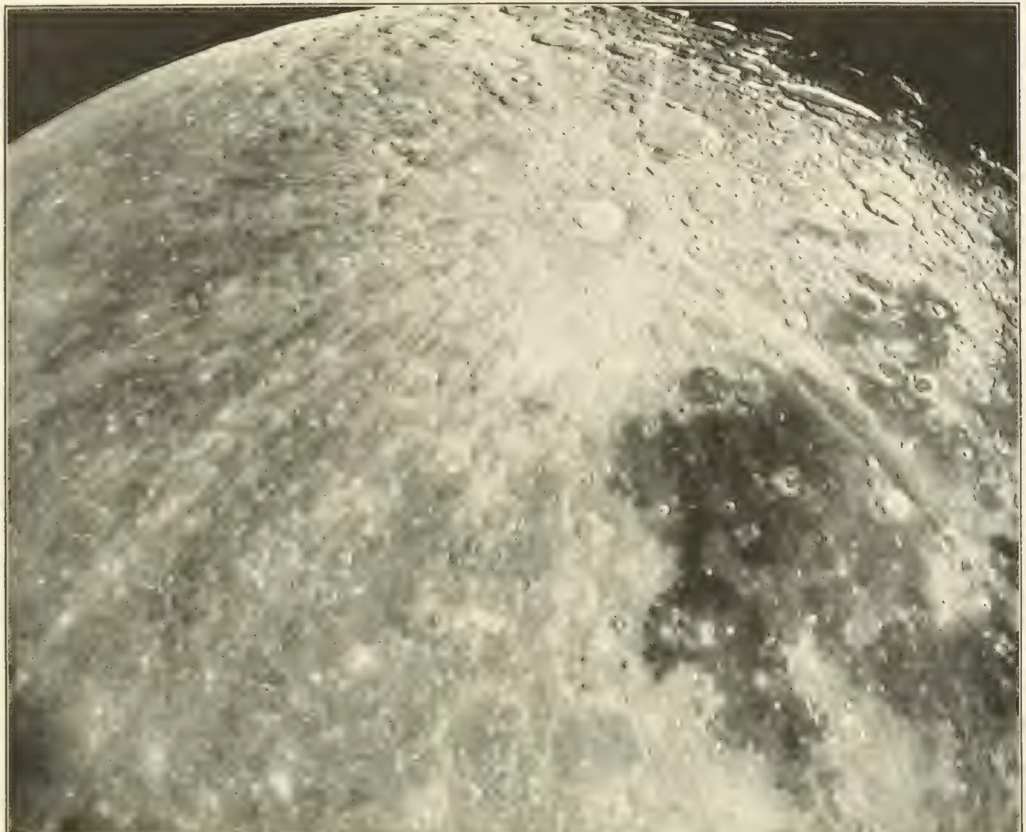
PLATE VII.

Copernicus and Kepler. Photographed by Ritchey with the 40-inch Yerkes refractor, with color screen and isochromatic plate.

The most important features exhibited here are the systems of bright rays of Copernicus, Kepler, and Aristarchus. These three ray systems, though less extensive than those of Tycho, taken together constitute the greatest exhibition of the bright bands that exist over the northern part of the surface. The complex branched nature of these bands is particularly well shown—better, indeed, than the writer has ever been able to note with the telescope. The fact that the bright bands of each system are prolongations of a central bright field is tolerably well shown.

Although owing to the high sun and the consequent absence of shadows, Copernicus in this view hardly appears as an elevation, it is, under favorable conditions of illumination, perhaps the noblest object on the moon. The wall on the eastern side, according to the estimates of Schmidt, rises to a height of 12,000 feet above the adjacent plain. The outer slopes of the cone are strongly ridged as by the flow from the crater of lavas which cooled on the steep slopes; some of these are faintly traceable in the plate.

COPERNICUS AND KEPLER. PHOTOGRAPHED BY RITCHEY WITH 40-INCH YERKES REFRACTOR, WITH COLOR SCREEN AND ISOCHROMATIC PLATE.



RAY SYSTEM ABOUT TYCHO. PHOTOGRAPHED BY RITCHEY.

PLATE VIII.

Ray system about Tycho. Photographed by Ritchey.

This, the most extensive of the ray systems of the moon, has its origin in the field about Tycho, the large vulcanoid to which the numerous bands apparently converge. It appears under the high sun as a large pit with a compound central cone. The rays of this system should be compared with those which have their centers in Copernicus and Kepler. In these last-named groups the streaks are developed on relatively level ground, while on that of Tycho they intersect a rugged surface.

On the right hand, some of the bands may be seen crossing the Mare Nubium. Two of them, of great length, are seen to be nearly parallel for a distance of some hundred miles.

A number of large vulcanoids, partly in shadow, are shown on the southeast margin of the moon. Of these, the largest is Schiller. Its length, which is 112 miles, will serve as a scale in estimating that of the rays.

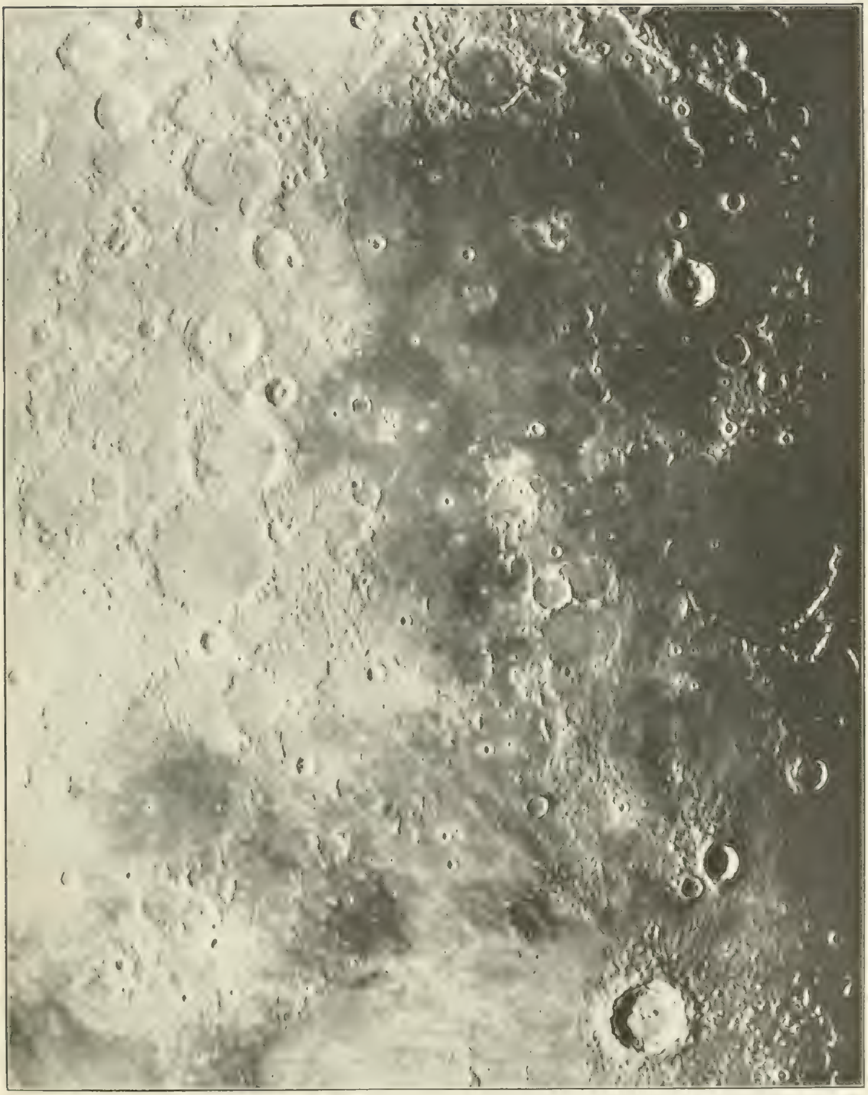
PLATE IX.

Mare Nubium and surroundings. Photographed by Ritchey, November 21, 1901, 7 hours 32 minutes p. m. Exposure, 1 second.

In this plate Copernicus is the large vulcanoid on the lower margin. The large crater near the upper margin, a little to the right of the center, with a cone somewhat to the right of its center and "rill" on its floor, is Pitatus. The three great vulcanoids in a row extending in a north-and-south direction are, in succession from the lowest toward the upper margin of the plate, Ptolemæus, Alphonsus, and Arzachel. The large, deep crater below and to the right of Pitatus, with a divided central cone, is Bullialdus.

The most noteworthy features in this plate are found in the many instances in which the lavas of the maria have partly destroyed the vulcanoids within their fields. In the upper right-hand fourth of the plate there are a dozen or more of these ruined craters, some of them with their walls almost effaced. In this part of the field there are several important rills. Some of these are evidently rows of craterlets in which the adjacent walls of the pits have been broken down so as to form a ragged cleft. A number of these lines of craterlets are traceable on the external slopes of Copernicus. The long, dark line, 65 miles in length, in the upper third of the plate, a little to the left of the center, is the Straight Wall, the most extensive fault known on the moon. The height of its cliff is about 500 feet. The crescent-shaped structure at its southern (upper) end is the remnant of a crater, the remainder of the margin having been destroyed by the lava of the mare. To the right of and near by the Straight Wall is a rill extending in a slightly curved course for a length of about 40 miles, terminating at either end in a distinct craterlet.

The brightly illuminated part of the field depicted on this plate, that to the left of the center, exhibits many excellent examples of crater valleys, which in their series afford something like a passage from the condition of rills to those of wider depressions.



MARE NUBIUM AND SURROUNDINGS.

Photographed by Ritchey, November 21, 1901, 7 hours 32 minutes p. m. Exposure, 1 second.

MARE TRANQUILITATIS AND SURROUNDINGS.

Photographed by Ritchey, August 3, 1901, 2 hours 30 minutes a. m., central standard time. Exposure, three-fourths second.

PLATE X.

Mare Tranquilitatis and surroundings. Photographed by Ritchey, August 3, 1901, 2 hours 30 minutes a. m., central standard time. Exposure, three-fourths second.

This plate includes nearly the whole of the Mare Tranquilitatis and, on the lower margin, a portion of the M. Serenitatis. The large crater near the strait connecting these maria is Plinius. The highland nearest to it is the promontory of Acherusia. On the southern, or upper, margin the view extends to the flanks of Theophilus.

The most noteworthy features are the mountain ridges on the maria, the manner in which the maria come in contact with the higher ground, the numerous crater valleys, and the great "rills."

It may be noted that ridges on the maria exhibit little trace of corresponding troughs between them, such as are usually found in terrestrial mountain chains.

The contact of the maria with the high ground has evidently resulted in the partial melting of the walls of several vulcanoids. Where these structures are not thus affected they are, apparently, in origin later than the formation of the maria. The crater valleys are abundant on the right-hand or eastern side of the field. Certain of them have been invaded by the lava of the mare.

Some of the greater rills are very well shown. That on the extreme right side is Hyginus. It will be observed that the course of these rills is at high angles to the prevailing direction of the ridges on the mare.

THE PRESSURE DUE TO RADIATION.[a]

By E. F. Nichols and G. F. Hull.

As early as 1619 Kepler[b] announced his belief that the solar repulsion of the finely divided matter of comets' tails was due to the outward pressure of light. On the corpuscular theory of light, Newton[c] considered Kepler's idea as plausible enough, but he was of the opinion that the phenomenon was analogous to the rising of smoke in our own atmosphere. In the first half of the eighteenth century De Mairan and Du Fay[d] contrived elaborate experiments to test this pressure-of-light theory in the laboratory, but, because of the disturbing action of the gases surrounding the illuminated bodies employed in the measurements, they obtained wholly confusing and contradictory results. Later in the same century Rev. A. Bennet[e] performed further experiments, but could find no repulsive force not traceable to convection currents in the gas surrounding the body upon which the light was projected, due, in his opinion, to the heating effect of the rays. Finding no pressure due to radiation, he made the following unique suggestion in support of the wave theory of light:

> Perhaps sensible heat and light may not be caused by the influx or rectilinear projection of fine particles, but by the vibrations made in the universally diffused caloric or matter of heat or fluid of light. I think modern discoveries, especially those of electricity, favor the latter hypothesis.

In the meantime Euler,[f] accepting Kepler's theory attributing the phenomenon of comets' tails to light pressure, had hastened to the

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[a] Presented to the American Academy of Arts and Sciences, December, 1902. Reprinted from the Astrophysical Journal, Vol. XVII, No. 5, June, 1903, omitting some of the tabulated results of experiments.

[b] De Mairan, Traité physique et historique de l'Aurore boréale (2d ed.), pp. 357, 358. Paris, 1754.

[c] Isaaci Newtoni Opera quæ Existant Omnia. Samuel Horsley, LL.D., R. S. S., Tom. III, pag. 156. Londinium, 1782.

[d] De Mairan, loc. cit., p. 371. This treatise contains also the accounts of still earlier experiments by Hartsoeker, p. 368, and Homberg, p. 369. The later experiments are of more historic than intrinsic interest.

[e] A. Bennet, Phil. Trans., p. 81, 1792.

[f] L. Euler, Histoire de l'Académie royale de Berlin (2), p. 121, 1746.

support of the wave theory by showing theoretically that a longitudinal wave motion might produce a pressure in the direction of its propagation upon a body which checked its progress. In 1825 Fresnel[a] made a series of experiments, but arrived at no more definite conclusion than that the repulsive and attractive forces observed were not of magnetic nor electric origin.

Crookes[b] believed in 1873 that he had found the true radiation pressure in his newly invented radiometer, and cautiously suggested that his experiments might have some bearing on the prevailing theory of the nature of light. Crookes's later experiments and Zöllner's[c] measurements of radiometric repulsions showed that the radiometric forces were in some cases 100,000 times greater than the light pressure forces with which they had been temporarily confused. Zöllner's experiments are among the most ingenious ever tried in this field of work, and he missed the discovery of the true radiation pressure by only the narrowest margin. An excellent bibliography of the whole radiometric literature is given by Graetz,[d] and an account of some of the older experiments not mentioned above is given by Crookes.[e]

In 1873 Maxwell,[f] on the basis of the electromagnetic theory, showed that if light were an electromagnetic phenomenon, pressure should result from the absorption or reflection of a beam of light. After a discussion of the equations involved, he says:

> Hence in a medium in which waves are propagated there is a pressure in the direction normal to the waves and numerically equal to the energy in unit volume.

Maxwell computed the pressure exerted by the sun on the illuminated surface of the earth, and added:

> It is probable that a much greater energy of radiation might be obtained by means of the concentrated rays from an electric lamp. Such rays falling on a thin metallic disk, delicately suspended in a vacuum, might perhaps produce an observable mechanical effect.

Apparently independent of Maxwell, Bartoli[g] announced in 1876 that the second law of thermodynamics required the existence of a pressure due to radiation numerically equal in amount to that derived by Maxwell. Bartoli's reasoning holds for all forms of energy streams in space, and is of more general application than Maxwell's equations. Bartoli contrived elaborate experiments to verify this theory, but was balked in the search, as all before him had been, by the complicated

[a] A. Fresnel, Ann. Chem. et Phys., 29, 57, 107, 1825.

[b] W. Crookes, Phil. Trans., p. 501, 1873.

[c] F. Zöllner, Pogg. Ann., 160, 156, 296, 459, 1877.

[d] L. Graetz, Winkelmann's Handbuch der Physik, 2b, p. 262. Breslau, 1896.

[e] W. Crookes, loc. cit., p. 501.

[f] J. C. Maxwell, A Treatise on Electricity and Magnetism (1st ed.) 2, 391. Oxford, 1873.

[g] A. Bartoli, Sopra i movementi prodotti della luce et dal calorie, Florence, Le Monnier, 1876; also Nuovo Cimento, 15, 193, 1884.

character of the gas action, which he found no way of eliminating from his experiments.

After Bartoli's work, the subject was dealt with theoretically by Boltzmann,[a] Galitzine,[b] Guillaume,[c] Heaviside,[d] and more recently Goldhammer,[e] Fitzgerald,[f] Lebedew,[g] and Hull[h] have discussed the bearing of radiation pressure upon the Newtonian law of gravitation, with special reference to the repulsion of comets' tails by the sun. The theory of radiation pressure, combined with the known properties in negative electrons, has recently been more or less speculatively applied by Arrhenius[i] to the explanation of many cosmical and terrestrial phenomena, among which the following may be mentioned: The solar corona, zodiacal light, gegenschein, comets, origin of cometary and meteoric material in space, the emission of gaseous nebulæ, the peculiar changes observed in the nebula surrounding Nova Persei, the northern lights, the variations in atmospheric electricity and terrestial magnetism and in the barometric pressure. Schwarzschild[j] computed from radiation pressure on small spherical conductors the size of bodies of unit density for which the ratio of radiation pressure to gravitational attraction would be a maximum.

Before the Congrès international de Physique in 1900, Professor Lebedew,[k] of the University of Moscow, described an arangement of apparatus which he was using at that time for the measurement of light pressure. He summarizes the results already obtained as follows:

Les résultats des mesures que j'ai faites jusqu'ici peuvent se résumer ainsi: L'expérience montre qu'un faisceau lumineux incident exerce sur les surfaces planes absorbantes et réfléchissantes des pressions qui, aux erreurs près d'observation, sont égales aux valeurs calculées par Maxwell et Bartoli.

No estimate of the "errors of observation" was given in the paper, nor other numerical data. Unfortunately the proceedings of the Paris Congress did not reach the writers, nor any intimation of the methods or results of Professor Lebedew's work, until after the publication of their own preliminary experiments.

[a] L. Boltzmann, Wied. Ann. 22, 31, 291, 1884.

[b] B. Galitzine, Wied. Ann., 47, 479, 1892.

[c] Ch. Ed. Guillaume, Arch. de Gen. (3), 31, 121, 1894.

[d] O. Heaviside, Electromagnetic Theory, 1, 334. London, 1893.

[e] D. A. Goldhammer, Ann. der Phys., 4, 834, 1901.

[f] G. F. Fitzgerald, Proc. Roy. Soc. Dub., 1884.

[g] P. Lebedew, Wied. Ann., 45, 292, 1892; Astrophysical Journal, 14, 155, 1902.

[h] G. F. Hull, Trans. Astron. Soc. Toronto, p. 123, 1901.

[i] S. A. Arrhenius, Lehrbuch der kosmischen Physik, Leipzig, 1903, pp. 149–158, 200–208, 226, 920–925.

[j] K. Schwarzschild, Kgl. bayer. Akademie d. Wissenschaften, 31, 293, 1901.

[k] P. Lebedew, Rapports présentés au Congrès international de Physique (2), p. 133. Paris, 1900.

The writers[a] presented the results they had obtained by measurements of radiation pressure at eight different gas pressures, in a preliminary communication to the American Physical Society, meeting with Section B of the American Association at Denver, August 29, 1901. The main arguments underlying the method of measurement of the radiation pressure may here be given.

In the experiments of earlier investigators every approach to the experimental solution of the problem of radiation pressure had been balked by the disturbing action of the gases which it is impossible to remove entirely from the space surrounding the body upon which the radiation falls. The forces of attraction or repulsion, due to the action of gas molecules, are functions, first, of the temperature difference between the body and its surroundings, caused by the absorption by the body of a portion of the rays which fall upon it; and, second, of the pressure of the gas surrounding the illuminated body. In the particular form of apparatus used in the present study, the latter function appears very complicated, and certain peculiarities of the gas action remain inexplicable upon the basis of any simple group of assumptions which the writers have so far been able to make.

Since we can neither do away entirely with the gas nor calculate its effect under varying conditions, the only hopeful approach which remains is to devise apparatus and methods of observation which will reduce the errors due to gas action to a minimum. The following considerations led to a method by which the elimination of the gas action was practically accomplished in the present experiments:

1. The surfaces which receive the radiation, the pressure of which is to be measured, should be as perfect reflectors as possible. This will reduce the gas action by making the rise of temperature due to absorption small, while the radiation pressure will be increased; the theory requiring that a beam totally reflected shall exert twice the pressure of an equal beam completely absorbed.

2. By studying the action of a beam of constant intensity upon the same surface surrounded by air at different pressures certain pressures may be found where the gas action is less than at others.

3. The apparatus—some sort of torsion balance—should carry two surfaces symmetrically placed with reference to the rotation axis, and the surfaces of the two arms should be as nearly equal as possible in every respect. The surfaces or vanes should be so constructed that if the forces due to gas action (whether suction or pressure on the warmer surface) and radiation pressure have the same sign in one case, a reversal of the suspension should reverse the gas action and bring the two forces into opposition. In this way a mean of the forces on the two faces of the suspension should be, in part at least, free from gas action.

[a] E. F. Nichols and G. F. Hull, Science, 14, 588 (October 18, 1901); Phys. Rev., 13, 293 (November, 1901); Astrophysical Journal, 15, p. 62 (January, 1902).

4. Radiation pressure, from its nature, must reach its maximum value instantly, while observation has shown that gas action begins at zero and increases with length of exposure, rising rapidly at first, then more slowly to its maximum effect, which, in many of the cases observed, was not reached until the exposure had lasted from two and a half to three minutes. For large gas pressures an even longer exposure was necessary to reach stationary conditions. The gas action may be thus still further reduced by a ballistic or semiballistic method of measurement.

In the number of the Annalen der Physik for November, 1901, Professor Lebedew[a] published the results of a more varied series of measurements of radiation pressure than the early measurements of the present writers.

Professor Lebedew's[b] estimate of the accuracy of his work is such as to admit of possible errors of 20 per cent in his final results. An analysis of Professor Lebedew's paper and comparison with our preliminary experiments seem to show that his accidental errors were larger than ours, but through an undiscovered false resistance in the bolometer our final results were somewhat further from the theory than his. Either of the above researches would have been sufficient to establish the existence of a pressure due to radiation, but neither research offered, in our judgment, a satisfactory quantitative confirmation of the Maxwell-Bartoli theory.

LATER PRESSURE MEASUREMENTS.

Description of apparatus; the torsion balance.—The form of suspension of the torsion balance, used to measure radiation pressure in the present study, is seen in fig. 1. The rotation axis *a b* was a fine rod of drawn glass. A drawn-glass cross arm *c*, bent down at either end into a small hook, was attached to the axis. The surfaces C and D, which received the light beam, were circular microscope cover-glasses, 12.8 mm. in diameter and 0.17 mm. thick, weighing approximately 51 mg. each. To distinguish the two vanes from each other, in case individual differences should appear in the measurements, and also to mark the two faces of each vane for subsequent recognition, a letter C was marked on one and D on the other by diamond scratches. Through each glass a hole 0.5 mm. or less in diameter was drilled near the edge, by means of which the glasses could be hung on the hooks on the cross arm *c*. On opposite sides of the rotation axis at *d* two other drawn-glass cross arms were attached. The cover-glasses slipped easily between these, and were thus held securely in one plane.

[a] P. Lebedew, Ann. der Phys., 6, 433, 1901.
[b] P. Lebedew, Ann. der Phys., 6, 457, 1901.

Farther down on ab a small silvered plane mirror m_1 was made fast at right angles to the plane of C and D. This mirror was polished bright on the silver side, so that the scale at S_5 (fig. 2) could be read in either face. A small brass weight m_3 (fig. 1), of 452 mg. mass and of known dimensions, was attached at the lower end of ab. The cover-glasses which served as vanes were silvered and brilliantly polished on the silvered sides, and so hung on the small hooks that both silver faces or both glass faces were presented to the light. A quartz fiber f_2, 3 cm. long, was made fast to the upper end of ab, and to the lower end of a fine glass rod d_1, which carried a horizontal magnet m_2. The

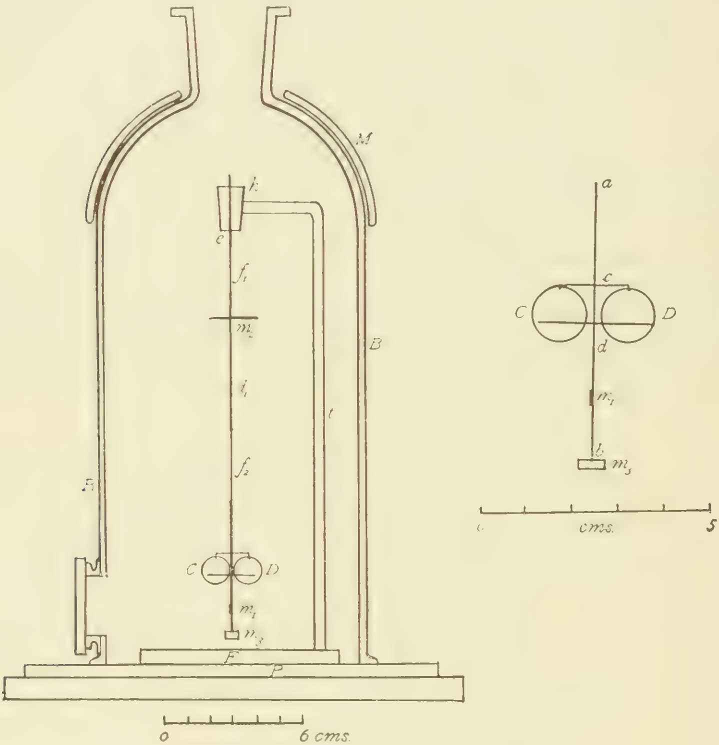

FIG. 1.

rod d_1 was in turn suspended by a short fiber to a steel pin e, which could be raised or lowered in the bearing h. The whole was carried by a bent glass tube t, firmly fastened to a solid brass foot F, resting on a plane ground-glass plate P, cemented to a brass platform mounted on three leveling screws not shown. A bell jar B, 25 cm. high and 11 cm. in diameter, covered the balance. The flange of the bell jar was ground to fit the plate P. A ground-in hollow glass stopper fitted the neck of the bell jar, which could thus be put in connection with a system of glass tubes leading to a Geissler mercury pump, a MacLeod pressure gauge, and a vertical glass tube dipping into a

mercury cup and serving as a rough manometer for measuring the larger gas pressures employed during the observations. The low pressures were measured on the MacLeod gauge in the usual way. A semicircular magnet M, fitted to the vertical curvature of the bell jar, was used to direct the suspended magnet m_2 and thus to control the zero position of the torsion balance. By turning M through 180°, the opposite faces of the vanes C and D could be presented to the light.

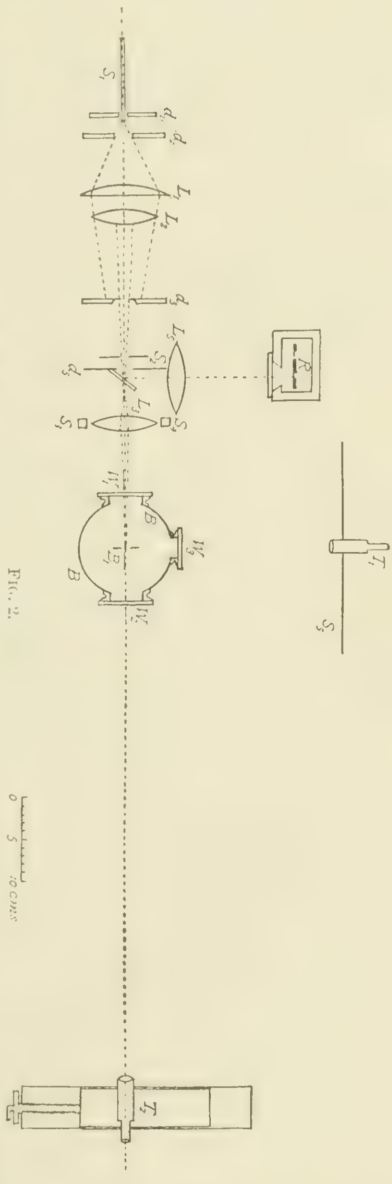

Fig. 2.

THE ARRANGEMENT OF APPARATUS.

A horizontal section of the apparatus through the axis of the light beam is shown in fig. 2. The white-hot end of the horizontal carbon S_1 of an A. T. Thompson 90° arc lamp, fed by alternating current, served as a source. The arc played against the end of the horizontal carbon from the vertical carbon, which was screened from the lenses L_1 and L_2 by an asbestos diaphragm d_2. A lens, not shown, projected an enlarged image of the arc and carbons on an adjacent wall, so that the position of the carbons and the condition of the arc could be seen at all times by both observers.

The cone of rays passing through the small diaphragm d_2 fell upon the glass condensing lenses L_1, L_2.

At d_3 a diaphragm, 11.25 mm. in diameter, was interposed, which permitted only the central portion of the cone of rays to pass. Just beyond d_3 the beam passed to a shutter at S_2. This shutter was worked by a magnetic escapement, operated by the second's contact of a standard clock. The observer at T_1 might choose the second for opening or closing the shutter, but the shutter's motion always took place at the time of the second's contact in the clock. Any exposure was

thus of some whole number of seconds' duration. The opening in the shutter was such as to let through, at the time of exposure, all of the direct beam which passed through d_3, but to shut out stray light. Just beyond the shutter and attached to the diaphragm d_5 was a 45° glass plate, which reflected a part of the beam to the lens L_5, by means of which an image of d_3 was projected upon one arm of a bolometer at R. The glass lens L_3 focused a sharp image of the aperture d_3 in the plane of the vanes of the torsion balance B_1, under the bell jar. The bell jar was provided with three plate-glass windows W_1, W_2, W_3. The first two gave a circular opening 42 mm. in diameter, and through the third deflections of the balance were read by a telescope and scale. The lens L_3 was arranged to move horizontally between the stops S_3 and S_4. These were so adjusted that when the lens was against S_3 the sharp image of the aperture d_3 fell centrally upon one vane; and when against S_4 the image fell centrally upon the

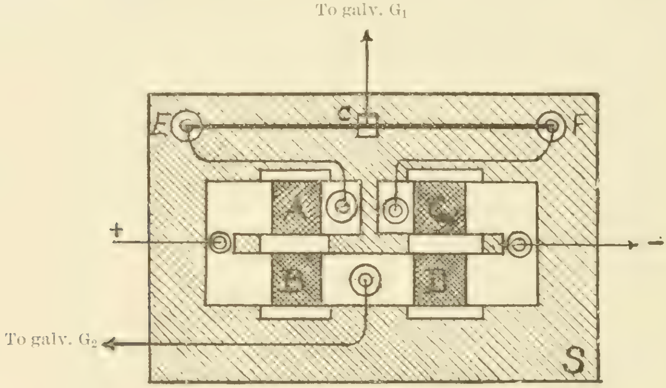

FIG. 3.

other. This adjustment, which was a very important one, was made by the aid of a telescope T_2, mounted on the carriage of a dividing engine. This was used to observe and measure the position of the rotation axis, as well as the positions of the images of d_3, when the lens L_3 was against the stops. For the latter measurements the vanes could be moved out of the way by turning the suspension through 90° by the control magnet M (fig. 1).

To make sure that the balance as used was entirely free from any magnetic moment or disturbance, the small magnet m_2 was clamped in one position to maintain a constant zero, and the period of the balance was accurately measured with the axis of the large magnet M in the vertical plane of the vanes and again when the axis was at right angles to the plane of the vanes. Several series of this sort failed to show a difference of 0.1 second in the period of the balance for the two positions of the magnet.

The bolometer at R (fig. 2) was of sheet platinum, 0.001 mm. thick, rolled in silver. The strip was cut out in the form shown in fig. 3 and mounted on a thin sheet of slate S. Two windows had been cut in the slate behind the strips at ABCD where the silver had been removed, leaving the thin platinum. The platinum surfaces were blackened by Kurlbaum's process. The image from L_5 (fig. 2) fell at D. The silver ends between A and C were connected with E and F, respectively. On the heavy wire EF a sliding contact c served to balance the bridge, all four arms of which are shown in the figure.

METHODS OF OBSERVATION.

The observations leading to the results given later were of three different kinds: (1) the calibration of the torsion balance; (2) the measurement of the pressure of radiation in terms of the constant of the balance, and (3) the measurement of the energy of the same beam in erg-seconds by the rate of temperature rise of a blackened silver disk of known mass and specific heat.

1. The determination of the constant of the torsion balance was made by removing the vanes C and D and accurately measuring the period of vibration. Its moment of inertia was easily computed from the masses and distribution of the various parts about the axis of rotation. The moment of torsion for 1 mm. deflection on a scale 105 cm. distant was 0.363×10^{-5} dyne$\times$cm. This value divided by one-half the distance between the centers of the light spots on the two vanes gave the force in dynes per scale division deflection. As the light spots were circles 11.25 mm. in diameter, the area of the image was very nearly 1 cm.^{2}; hence the above procedure gave roughly the pressure in dynes per square centimeter.

2. In the measurements of radiation pressure it was easier to refer the intensity of the beam at each exposure to some arbitrary standard which could be kept constant than to try to hold the lamp as steady as would otherwise have been necessary. For this purpose, the bolometer at R (fig. 2) was introduced, and simultaneous observations were made of the relative intensity of the reflected beam by the deflection of the galvanometer G_2 and the pressure due to the transmitted beam by the deflection of the torsion balance. The actual deflection of the balance was then reduced to a deflection corresponding to a galvanometer deflection of 100 scale divisions. The galvanometer sensitiveness was carefully tested at the beginning and end of each evening's work. All observations of pressure were thus reduced to the pressure due to a beam of fixed intensity.

At each series of radiation pressure measurements two sets of observations were made. In one of these sets static conditions were observed, and in the other the deflections of the balance due to short

exposures were measured. In the static observations each vane of the balance was exposed in turn to the beam from the lamp, the exposures lasting until the turning points of the swings showed that stationary conditions had been reached. The moment of pressure of radiation and gas action combined would thus be equal to the product of the static deflection and the constant of the balance. The torsion system was then turned through 180° by rotating the outside magnet, and similar observations were made on the reverse side of the vanes. All turning points of the swinging balance in these observations were recorded. From the data thus obtained the resultant of the combined radiation and gas forces could be determined for the time of every turning point. Every value was divided by the deflection at standard sensitiveness of the galvanometer G_2 read at the same time, and was thus reduced to standard lamp. Results thus obtained, together with the ballistic measurements, showed the direction and extent of the gas action as well as its variation with length of exposure.

The reasons for reversing the suspension follow: The beam from the lamp, before reaching the balance, passed through three thick glass lenses and two glass plates. All wave lengths destructively absorbed by the glass were thus sifted out of the beam by the time it reached the balance vanes. The silver coatings on the vanes absorbed, therefore, more than the glass. The radiation pressure was always away from the source, irrespective of the way the vanes were turned, while the gas action would be exerted mainly on the silvered sides of the vanes.

At the close of the pressure and energy measurements, when the reflecting power of the silver faces of the vanes was compared with that of the glass-silver faces, the reflection from the silver faces was found very much higher than that for the glass faces backed by silver. This result was the more surprising because the absorption of the unsilvered vanes was found by measurement to be negligibly small.[a] This unexpected difference in reflecting power of the two faces of the mirrors prevented the elimination of the gas action, by the method described, from being as complete as had been hoped for. But by choosing a gas pressure where the gas action after long exposure is small, the whole gas effect during the time of a ballistic exposure may be so reduced as to be of little consequence in any case.

By exposing each of the vanes in turn and by reversing the suspension and averaging results, nearly all errors due to lack of symmetry in the balance or in the position of the light images with reference to the rotation axis, or errors due to lack of uniformity in the distribution of intensity in different parts of the image, could be eliminated.

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[a] Lord Rayleigh records a similar difference between the reflection from air-silver and glass-silver surfaces. Scientific papers, Cambridge, 2, 538–539, 1900.

The changing character of the gas action, both with time of exposure and gas pressure surrounding the balance vanes, is well illustrated in eight series of static observations in which the glass faces of both vanes were exposed.[a] The results obtained on the two vanes were averaged and plotted as curves in fig. 4, where static deflections due

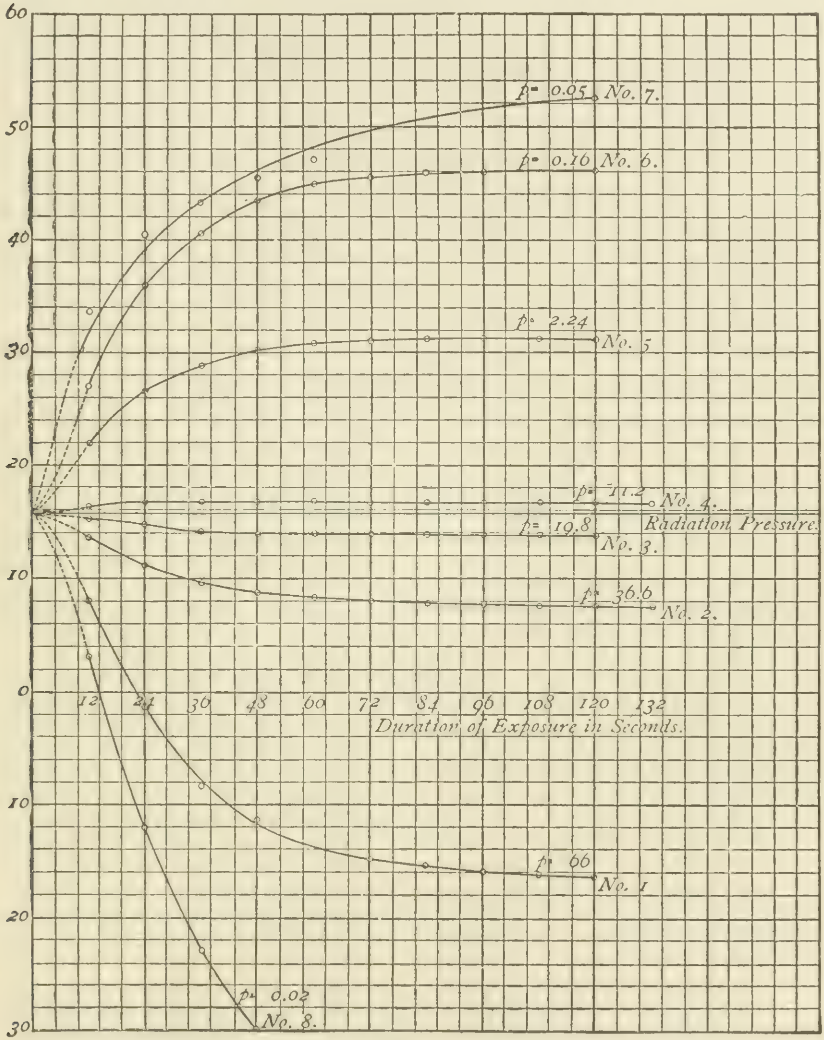

FIG. 4.

to combined radiation pressure and gas action are shown as ordinates and duration of exposure, in seconds, as abscissæ.[b] A horizontal line

[a] Observations were also made on the silver faces, but the gas action when the glass faces were exposed was nearly double that for the silver faces, so the least favorable case is shown.

[b] Ordinates of the curves are proportional to moments.

through the diagram gives the mean value of the moment of radiation pressure computed from the data in Table I. Decrease of the deflection with time indicates gas repulsion on the warmed silver faces and increase in deflection gas suction. It will be seen from the curves that beginning at a gas pressure of 66 mm. of mercury, the gas action was repulsion changing to suction in passing from 19.8 to 11.2 mm. In the last two cases the total gas action is small. For lower pressures the suction increases to 0.05 mm. At a gas pressure of 0.02 mm. the gas action is again a strong repulsion.

The curves indicate the existence of two gas pressures, at which the gas action in our arrangement of apparatus should be zero, one between 19.8 and 11.2 mm. and the other between 0.05 and 0.02 mm.[a] The former region was chosen for the ballistic measurements and nearly all of the observations were made at a gas pressure of approximately 16 mm. Even for the two pressures where the decrease in the static deflection was most rapid, i. e., at gas pressures of 66 and 0.02 mm., the first throw was always in the direction of radiation pressure. The gas action is strongly influenced by very slight changes in the inclination of the plane of the vanes to the vertical and also by any object introduced under the bell jar anywhere near the vanes. For instance, a very considerable effect was observed when a small vessel of phosphoric anhydride was placed under the jar behind the vanes, though the nearest wall of the vessel was separated from the vanes by a distance of at least 3 cm.

During the observations, the polished silver coatings on the vanes deteriorated rapidly; new coatings rarely lasted for more than two evenings' work. As the balance had to be removed and the mirrors taken from the hooks, silvered, polished, and replaced a great number of times during the entire series of measurements, although great care was taken in setting the plane of the vanes vertical, it is not likely that precisely the same conditions for gas action were ever repeated. The principal value of the static results was in indicating favorable gas pressures for work, rather than affording quantitative estimates of the gas action in short exposures. The dotted parts of the curves are not based on results of observation and might perhaps have been omitted without loss.

It was plain, therefore, that further elimination of the gas action must be sought in exposures so short that the gas action would not have time to reach more than a small fraction of its stationary value. This led to the method of ballistic observations.

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[a] Crookes in his work with the radiometer discovered certain gas pressures for which the combined gas and radiation forces neutralized, but as he did not discriminate between forces due to radiation and gas forces his results were apparently capricious and his reasoning somewhat confused. See Phil. Trans., p. 519, 1875.

THE BALLISTIC OBSERVATIONS.

In passing from the static to the ballistic observations it must always be possible to compute the static equivalent of the ballistic swings. Furthermore, the exposures should be made as short as possible without reducing the size of the swing below a value which can be accurately measured.

If the exposure lasts for one-half the period of the balance, the deflection, if the gas action be small, and the damping zero, is equal to 2θ where θ is the angle at which the torsion of the fiber will balance the moment produced by the radiation pressure. If the duration of the exposure be one-quarter of the period of the balance, the angle of deflection is $\theta\sqrt{2}$. The deflection is thus reduced by 30 per cent, but the effect of the gas action is reduced in greater porportion. It was decided, therefore, to expose for six seconds, one-fourth of the balance period. Neglecting the gas action, but taking account of the damping of the system, it may be shown that the total angle of deflection of the torsion balance in the ballistic measurements is equal to 1.357 times the angle at which the torsion moment balances the moment of the radiation pressure.

To make sure that the observed radiation pressures depended only on the intensity of the beam, and were uninfluenced by the wave length of the incident energy, the ballistic observations of pressure, the thermal measurements of intensity, and the determination of the reflection coefficients were carried out for three entirely different wave groups of the incident radiation. In the measurements designated "through air" no absorbing medium was introduced in the path of the beam between the lamp and the balance except the glass lenses and plates already mentioned. In the measurements "through red glass" a plate of ruby glass was put in the path of the beam between L_2 and d_3 (fig. 2). For the observations "through water cell" a 9-mm. layer of distilled water in a glass cell was placed in the path of the beam at the same point.[a]

Applying reduction factors to the averages in the separate series of measurements of radiation pressure, we find the pressure of the standard light beam which has passed

(*a*) through air to be $(7.01 \pm 0.023) \times 10^{-5}$ dynes;
(*b*) through red glass to be $(6.94 \pm 0.024) \times 10^{-5}$ dynes;
(*c*) through water cell to be $(6.52 \pm 0.028) \times 10^{-5}$ dynes.

[a] Here follow in the original paper detailed results of 14 separate series of measurements "through air," 8 "through water," and 9 "through red glass."

THE ENERGY MEASUREMENTS.

The radiant intensity of the beam used in the experiments was determined by directing it upon the blackened face of a silver disk, weighing 4.80 grams, of 13.3 mm. diameter, and of 3.58 mm. thickness, and by measuring its rate of temperature rise as it passed through the temperature of its surroundings. The disk was obtained from Messrs. Tiffany & Co., and was said by them to be 99.8 per cent fine silver. Two holes were bored through parallel diameters of the disk, one-fourth of the thickness of the disk from either face. Two iron constantan thermojunctions, made by soldering 0.1 mm. wires of the two metals, were drawn through the holes into the center of the disk. To insulate the wires from the disk, fine drawn-glass tubes were slipped over them and thrust into the holes, leaving less than 2 mm. bare wire on either side of the junctions. The wires were sealed into the tubes and the tubes into the disk by solid shellac. The tubes projected 15 mm. or more from the disk and were bent upward in planes parallel to the faces of the disk. The general arrangement will be seen in fig. 5. The disk was suspended by the four wires some distance below a small flat wooden box. On the box was fastened a calorimeter can swathed in cotton and filled with kerosene in which the constant thermojunctions were immersed. Copper wires soldered to the two ends of the thermoelectric series were brought out of the calorimeter, and the circuit was closed through 1,000 ohms in series with the 500 ohms resistance of galvanometer G_1.

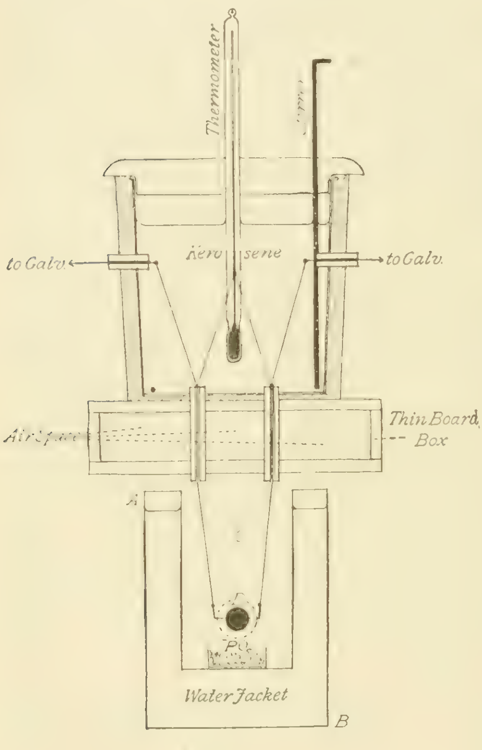

Fig. 5.

The thermojunctions in the disk were in series, and as each junction was midway between the central plane of the disk and either face, it was assumed that when the disk was slowly warmed by heating one face the electromotive forces obtained corresponded to the mean temperature of the disk. One face of the disk was blackened by spraying it with powdered lampblack in alcohol containing a trace of shellac.

This method was suggested by Prof. G. E. Hale and gives very fine and uniform dead-black coatings not inferior to good smoke deposits.

For the energy measurements the bell jar and the torsion balance were removed from the platform P (fig. 1) and a double-walled copper vessel AB (fig. 5), which served as a water jacket surrounding a small air chamber C, was mounted in the same place. A tube 2 cm. in diameter was soldered into the front face of the jacket to admit the light beam into the chamber C. This opening was covered by a piece of plate glass similar to the plates forming the larger windows in the bell jar.

The needle system in G_1, a four-coil du Bois-Rubens galvanometer, was suspended in a strong magnetic field so that its period was about four seconds. The system was heavily damped by a mica air fan of large surface. The disk junctions and galvanometer responded quickly to the radiation, as was shown by the reversal of motion of the magnet system 1.2 seconds after the light was cut off from the disk, when the latter was a few degrees above the temperature of the room.

The disk was calibrated for temperature in terms of the deflection for a definite sensitiveness of the galvanometer G_1. * * *

The mean of two separate calibrations taken several days apart was 9.96 scale divisions for one degree temperature difference.

Before beginning a series of intensity measurements the disk was suspended in an air chamber containing phosphoric anhydride and surrounded by a jacket of ice and salt. The disk was thus lowered to a temperature of about zero degrees and was then quickly transferred to the chamber C (fig. 5), and the beam was directed upon it. When its temperature had risen to within 5 or 6 degrees of that of the chamber C, galvanometer readings were made at intervals of five seconds until the disk was heated to a temperature several degrees above its surroundings. The temperature of the chamber C was determined by removing the disk and cooling it to a point near the room temperature, then replacing it and observing its rate of temperature change for several minutes.

Energy series were made "through air," "through red glass," and "through water cell," as in the pressure measurements. During the experiment the black coatings were frequently cleaned off from the disk and new ones deposited. The final result therefore does not correspond to an individual but to an average coating.

To correct for any inequality between the two disk thermojunctions or any lack of symmetry in their positions, referred to the central plane of the disk, which might prevent the mean temperature of the two junctions from representing the mean temperature of the mass, series of observations were made on each face of the disks. The black coating was always cleaned off from the face of the disk away from the light.[a]

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[a] In the original paper here follow detailed results of 82 energy measurements through air, water, and red glass, some on one face of the disk and some on the other.

As the general result of all the energy measurements it was found that the rise in temperature of the silver disk per second when the light passed:[a]

(*a*) through air $=(0^\circ.0970 \pm 0^\circ.00034)$ C.;
(*b*) through red glass $=(0^\circ.0946 \pm 0^\circ.00036)$ C.;
(*c*) through water cell $=(0^\circ.0884 \pm 0^\circ.00064)$ C.

The mass of the silver disk was 4.80 grams, its specific heat[b] at 18° C. $=0.0556$; the mechanical equivalent of heat at 18° C. $=4.272 \times 10^7$ ergs.[c] Consequently the energy of the standard radiation is

(*a*) through air, $0.0970 \times 4.80 \times 0.0556 \times 4.272 \times 10^7$
or $E_a = (1.108 \pm 0.004) \times 10^6$ ergs per second.
(*b*) through red glass, $E_g = (1.078 \pm 0.004) \times 10^6$ ergs per second.
(*c*) through water cell, $E_w = (1.008 \pm 0.007) \times 10^6$ ergs per second.

REFLECTING POWER OF THE SURFACES USED.

According to Maxwell and Bartoli, the pressure in dynes per square centimeter for normal incidence is equal to the energy in ergs in unit volume of the medium. The energy in unit volume is made up of both the direct and reflected beams. If E is the intensity of the incident beam and ρ the reflection coefficient, the pressure $p = \frac{E(1+\rho)}{V}$, where V is the velocity of light. The methods for measuring p and E have already been described. The determination of ρ for both sides of the vanes C and D was made by means of a bolometer.[d]

In all, three series of measurements were made on the silver and two series on the glass-silver faces of each vane. To get average coefficients which would represent the range of condition of the mirrors during the pressure measurements, the vanes were cleaned and new silver coatings deposited between each two series on the same vane. The reflection coefficients are as follows:

Connected reflection coefficients in percentages.

	Air silver.	Glass silver.
Through air	92.0	77.6
Red glass	93.4	76.2
Water	89.0	80.5

Average coefficients through air, 84.8; red glass, 84.8; water, 84.8.

The diffuse reflection of black coatings deposited by the method used in blackening the silver disk was measured and computed in the same manner as the diffused reflection from the vanes C and D. Five determinations of this reflection were made under different conditions

[a] See footnote to table on page 131.
[b] U. Behn, Ann. der Phys., 4, 266, 1900.
[c] Mean of Rowland's and Griffith's values. Phil. Trans., 5, 184, 496, 1893.
[d] In the original paper here follow the details of experiments on the reflecting power of the surfaces.

and with different coatings. The values in percentages of the incident beam averaged 4.6 per cent. Thus only 95.4 per cent of the incident beam was absorbed by the black coating on the silver disk in producing the temperature increase observed. Hence the true energy of the beam is equal to the observed energy divided by 0.954.

The silver disk, diameter 13.3 mm., used in the energy measurements, received long waves and scattered radiation which passed round and through the light-pressure vanes of diameter 12.8 mm. This amount was experimentally determined for both thin and thick silver coatings in order to approximate to the average condition of the coatings in the light-pressure measurements, and it was found to average (*a*) through air, 1.40 per cent; (*b*) through red glass, 1.44 per cent; (*c*) through water, 0.46 per cent. On this account the energy E of the standard radiation must be reduced by the above percentages.[a]

A comparison of observed and computed pressures follows:

	Observed values in 10^{-5} dynes.	Computed values in 10^{-5} dynes.	Differences.
			Per cent.
Through air	[a] $p=7.01\pm0.02$	7.05 ± 0.03	-0.6
Through red glass	$p=6.94\pm.02$	$6.86\pm.03$	$+1.1$
Through water	$p=6.52\pm.03$	$6.48\pm.04$	$-.6$

[a] The pressure and energy measurements for the three different wave groups through air, red glass, and water cell constitute three independent experiments. The values for pressure, 7.01, 6.94, and 6.52 in the three cases are only accidentally related. The difference arises from the different reflecting power of the 45° glass plate (fig. 2) for the different beams and from the fact that the indications of the lamp galvanometer G_2 connected with bolometer R were probably not strictly proportional to energy for throws differing as widely as 33, 60, and 100, which, roughly, were the relative intensities of the beams through water cell, red glass, and air. The function of the lamp bolometer and galvanometer was purely to keep a check on the small variations of the lamp, which rarely fluctuated more than 10 per cent on either side of the mean value.

An estimate of the approximate magnitude of the gas action not eliminated by the ballistic method of observation [of which details appear in the original paper] shows that the uneliminated gas action, by the most liberal estimate, can not have exceeded 1 per cent of the radiation pressure. Because of its smallness and indefiniteness no correction for gas action has been made to the final pressure values. If corrections were applied, its effect would be to reduce slightly the observed pressures.

From the agreement within the probable errors of the air, red glass, and water values with the theory it appears that radiation pressure depends only upon the intensity of the radiation and is independent of the wave length.

The Maxwell-Bartoli theory is thus quantitatively confirmed within the probable errors of observation.

Wilder Laboratory, Dartmouth College,

Hanover, N. H., February, 1903.

[a] As the average pitch of the cone of the incident beam was about 1 part in 40, no correction need be applied for inclination. Furthermore, the inside of the bell jar was blackened and the zero of the balance was so chosen that energy reflected from the window admitting the beam could produce no pressure effects.

THE APPLICATION OF RADIATION PRESSURE TO COMETARY THEORY.

In the experiments described in the foregoing paper the close agreement of theory with experiment warrants the rigid application of the radiation-pressure theory in the explanation of cosmical phenomena.

In any balancing of radiation pressure against gravitation in comets the size of particles is the determining factor. The repulsion due to radiation pressure depends upon the intensity of the rays, the absorbing and reflecting power of the surface, and the cross section of the body exposed. Gravitational attraction depends only upon mass, or the product of volume and density. It will be seen, therefore, that for spheres of a given substance the weight at a fixed distance from the sun will vary with the cube of the radius, while radiation pressure will depend upon the radius squared. The ratio of pressure to weight will thus be inversely as the radius. This relation holds down to the point where the particles become so small that they begin to lose in absorbing and reflecting power through diffraction.

The intensity of the solar radiation and gravitation diminish with distance in accordance with the same law, so that the ratio of pressure to weight is a constant for the same body at all distances from the sun.

For spheres of the same size, and the same absorbing and reflecting power, the ratio of pressure to gravitation is inversely as the density. The variation of this ratio, as it depends upon size and density, has been used by Lebedew[a] and Arrhenius[b] in the computation of the repulsion upon the finely divided matter of comets' tails, but the limiting value of the ratio for diminishing spheres of the same density due to diffraction first appears in Schwarzschild's paper.[c]

Comet heads.—In the heads of comets the phenomena are most complicated and difficult of explanation, yet it seems worth while to try to gather together a few of the separate causes which may be at work in producing this intricate structure.

The heat received from the sun by the nucleus of a comet may be spent in three ways: (1) In raising the temperature of the nucleus. As the nucleus is of relatively small mass and probably of low heat conductivity no very considerable quantity of heat is required for this purpose. (2) Heat may be, and doubtless is, used in the vaporization of volatile hydrocarbons and other substances in the nucleus. (3) Large quantities of heat are lost from the nucleus by radiation.

The porous structure of meteorites points to a similar structure in cometary nuclei. The jets from the nucleus outward to the envelope of the head may be formed by the heating of the vaporizable materials

[a] Wied. Ann., 45, 292, 1892; also Astrophysical Journal, 14, 155, 1902.

[b] Lehrbuch der kosmischen Physik, p. 150, Leipzig, 1903.

[c] Sitzungsberichte der math.-phys. Classe der k. b. Akademie der Wissenschaften zu München, 31, 293, 1901.

in the interior of the nucleus and the consequent shooting out under pressure of a mixture of gases and dust through holes in a loose outer crust. Lack of sufficient means of escape in this way may cause a bursting of the nucleus sometimes observed.

The general upward current of vapors from the nucleus to the envelope, aside from jets, may be due to convection away from the more strongly heated center.[a]

Because of the counter-pressure due to the radiation of the nucleus itself, the rising of even small solid particles from the nucleus to the envelope would not encounter as strong an unbalanced pressure from the solar rays as particles in the tail. For, if all the heat received from the sun were again radiated from the nucleus on the side toward the sun, these two counter-radiation pressures would exactly balance at the surface of the nucleus.[b]

Small particles may also be aided in rising from the nucleus toward the sun by gas forces. By numerous experiments on larger bodies immersed in a gas and illuminated on one side, it has been shown that they may be either repelled from the light source or drawn to it, depending upon the pressure of the surrounding gas. (See curves, in the foregoing paper, fig. 4.) If the gas pressure is not too low, particles after leaving the nucleus might first be drawn toward the sun until a region of higher vacuum was reached in the ascent, and then be repelled.[c]

The brilliant envelope of the head may be regarded as forming at the height where condensation, caused by expansion and cooling, takes place. Here the repelling action of the solar radiation would reach a high value and the particles in the envelope would be driven backward to form the tail.

According to Arrhenius[d] this condensation in the envelope is assisted

[a] Matter in the form of gases and vapors is not subject to radiation pressure, as solid and liquid particles are, because of the minuteness of molecular dimensions. Except in the spectrum regions of characteristic absorption, radiation can, theoretically, exert no pressure whatever upon a gas. Hence gases might rise from the nucleus toward the sun practically unhindered by radiation pressure.

[b] It is worth noting in this connection that the longer and invisible waves are as effective in producing pressure as the visible radiations, and that these long waves strongly preponderate in the spectra of solid bodies at temperatures low in comparison with the solar temperature.

[c] It is possible also that electrostatic forces may play a small part in the formation of the head from the nucleus. Arrhenius believes the sun to have a positive electrical charge, due to the fact that it loses more negative electrons by condensation into nuclei and subsequent repulsion by radiation pressure than it does of positive electrons which do not as readily serve as centers of condensation. Streams of negatively charged particles would communicate a negative charge to the matter surrounding the comet's nucleus, which would thus be attracted by the sun. As this attraction would oppose the formation of the tail in the same measure as it assisted that of the head, it can not be a dominating influence.

[d] L. c., p. 208.

by the influx of negatively charged nuclei from the sun, which serve as condensation centers for the ascending vapors. The height above the nucleus of the comet at which this condensation would occur would thus, in some measure, be governed by the supply of negative particles. These would be found in increasing numbers with diminishing distance from the sun. This action may be responsible for the contraction of the head and envelope as comets approach the sun.

The brilliancy of the envelope may be attributed in large part to the fact that bodies of sufficient size to reflect solar rays are first formed out of the vapors of the head in this region. The negative nuclei from the sun would here experience an obstruction and lose the greater part of their motion by friction. Electrical interchanges and discharges would be more active, and the hydrocarbon spectrum be brighter in the envelope than in other parts of the head.

If the brightness of the head and its envelope depend upon the number of negatively charged nuclei which strike the comet, and if, as Arrhenius maintains, the nuclei move out from the sun radially and in greatest numbers from regions of greater solar activity, comets crossing the surface defined by solar radii drawn through the sun-spot belts should show a marked increase in brightness, especially in maximum sun-spot years. The writers are not aware that any such influence has been looked for in the cases where sudden changes of brightness in comets have been observed.

Comet tails.—The maximum ratio of radiation pressure to gravitation, obtained theoretically by Schwarzschild for sunlight upon opaque reflecting spheres of 0.8 density, under the most favorable conditions, was about 20 to 1, if the recent estimates (ranging from 3.5 to 4) of the solar constant were used.

In Bredichin's three types of cometary tails the highest ratio of attraction to repulsion required is about 18 to 1. The multiple tails observed in such comets as Donati's may thus be satisfactorily explained by the sifting action of radiation pressure in two ways—either by assuming, with Bredichin, that the particles in the different tails are of different densities, but of uniform size, or by assuming uniform density and particles of several different sizes.

While radiation pressure alone may thus afford a satisfactory explanation of comets' tails, there is no reason to assume that it is the only cause of the repulsive action observed. There are several ways in which the gases and vapors present in the tail may exert a force upon the small solid or liquid particles which are known to exist there:

1. Small particles, if warmed on one side when surrounded by gases or vapors, even under pressures so low that electrical discharges take place only under relatively high voltages, experience a strong repulsion, similar to that upon a vane of a Crookes radiometer.

2. Occluded gases or volatile materials upon the surface of the particles would be driven off by the sun's heat on the illuminated sides, and the particles would thus receive a thrust in the direction away from the sun.

3. If the particles were porous or loosely put together, containing cavities filled with more easily vaporizable substances, the resulting vapors would be shot out upon the hotter sides and the particles driven back by a kind of rocket action.

That these combined gas forces are still large, even in high vacua, will be seen from an actual experiment described later.

If we accept Arrhenius's theory that the solar activity produces numberless negative electrons which serve as condensation points for the vapors surrounding them in the solar atmosphere, and thus form small, negatively charged nuclei, which are driven from the sun by radiation pressure,[a] these nuclei would exert a battering action upon the particles of the tail. In the last case a strange meeting point is found between the oldest, or Keplerian, and the latest explanation of the solar repulsion of comets' tails.

Finally Prof. J. J. Thomson,[b] in investigating the action of electric waves upon charged bodies immersed in the medium, has found that a small repulsive effect may arise from this cause. This repulsive force is entirely distinct from the radiation pressure so far considered, but on the electro-magnetic theory of light it may be competent to drive away electrons formed above the photosphere of the sun, independently of the sign of the charge and of whether they have formed nuclei by condensation or not.

These last two causes of repulsion are in all probability of very minor importance when compared with radiation pressure, or even with gas action.

Experiment with a laboratory comet's tail.—Some of the above considerations led the writers to try to reproduce, as nearly as possible, in a vacuum tube some of the conditions believed to exist in comets' tails. The result of a hasty computation of the magnitude of the effect which might be expected from radiation pressure provided a suitable dust could be found was most encouraging.

At the outset it was apparent that it would be very difficult to manufacture a powder the grains of which would be sufficiently small, light, and uniform for the purpose; so the spores of a great variety of degraded vegetable forms were examined. Finally a puffball of the genus *Lycoperdon* was discovered, the spores of which averaged 2 microns in diameter, and were as nearly spherical and uniform in size

[a] The supposed electrical discharges in the tail of a comet which give rise to its gaseous emission spectrum are attributed by Arrhenius to the electrical disturbances caused by the influx of these negative nuclei.

[b] Phil. Mag., 4, 253, 1902.

as a pile of apples from the same tree. These spores were light, cellular structures, filled mainly with oil. They were calcined by heating to redness and all the vaporizable material driven off, leaving only sponge-like charcoal spheres behind. The density of a mass of these spheres (individuals could obviously not be dealt with) was measured and found to be about one-tenth that of water. Making liberal allowances for the spaces between spheres in the pile, the density of a single sphere could not exceed 0.15.[a]

These spores, together with a quantity of emery sand, were placed in a glass tube the form of which was suggested by the hourglass. Smaller tubes led off from either end. One of these was fused to a good mercury pump of the Geissler type, the other bent down and joined to a small flask containing mercury.

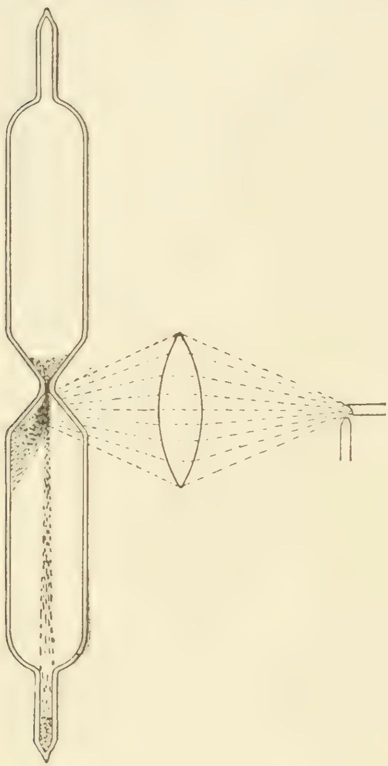

FIG. 1.

All of the tubes were wrapped with wire gauze and heated to a temperature just below the softening point of glass, and the pump was worked many hours. When the pump showed no further signs of gas the mercury in the flask was boiled and mercury vapor driven through the tubes to carry off any permanent gases which the pump alone could not reach. After this had continued for an hour or more the tube system was sealed off from the pump and the mercury flask was surrounded by solid carbon dioxide and ether, and the hourglass still heated. In this way all of the mercury vapor which could be condensed at a temperature of -80° C. was drawn out of the tubes. After nearly an hour the mercury flask with its frozen contents was sealed off from the hourglass.

The hourglass was then held in a vertical position and a beam of light of approximately known intensity was directed horizontally on the lower half of the tube just below the neck, fig. 1. By tapping the tube a fine stream of sand and charcoal puffball spores descended. The sand particles fell through the beam, showing no deflection, but the spores were driven from the stream sidewise in passing the beam.

[a] According to Schwarzschild's formula, the ratio of radiation pressure to solar gravitation for spheres of the size and density of these spores would be about 6 to 1.

The observed angle of deflection of the spores from the vertical was roughly that given from the computation, and the observers believed that the effects shown must be due almost entirely to light pressure, with possibly a slight gas action. The action of gases upon heated bodies of this size had, so far as we know, never been studied, but one of the writers[a] had studied the gas action on larger bodies down to a pressure of permanent gases of 0.0005 mm. of mercury, as shown by a McCleod gauge, and had observed that for this pressure the gas action had begun to fall off sharply. The pressure of the permanent gases in the hourglass must have been well below this value, and it was thought that nearly all pressure due to vapor had been frozen out.

Later, a review of the preliminary computation was made and an error discovered which had the effect of bringing out the computed light pressure on bodies of this size and density far too large. It was plain, therefore, that the force of deflection due to gas action, probably of the character of rocket action, was at least ten times as large as the effect attributable to radiation pressure. Radiation pressure alone would produce a measurable effect under the conditions of observation, but would have been far less pronounced than the effect obtained.

The experiment had unfortunately to be tried under circumstances much more unfavorable for a pronounced effect of radiation pressure than exists in comets, for the deflection produced by repulsion must be measured in terms of terrestrial gravitation, which is over 1,600 times as great as solar gravitation at the distance of the earth. To approach cometary conditions, therefore, it would have been necessary to use a light beam 1,600 times as intense as sunlight at the earth. In the experiment, beams from twenty to forty times as intense as sunlight were used.

Because of the meagerness of present knowledge concerning the actual conditions in comets' tails it is impossible to say how closely the foregoing experiment fulfilled the purpose for which it was tried. It would be difficult to prove from present astronomical data that the hydrocarbon vapors known to exist in comets' tails exert no radiometric repulsion upon the small reflecting particles present. Still more difficult would it be to show that nothing which corresponds to what has been called rocket action occurs. This latter repulsion does not require the presence of any generally diffused atmosphere whatever, but simply that the particles send off gases toward the sun under the action of the sun's heat. Thus, in passing from the era where no adequate physical causes which would meet the required conditions

[a] A result gained in a series of unpublished experiments on gas forces by W. v. Uljanin and E. F. Nichols. See also W. Crookes, Phil. Trans., p. 300, 1878.

could be assigned for the repulsion seen in comets, we are now likely to be embarrassed in discriminating between several contributing influences.

The writers hope to repeat the comet's tail experiment, using smaller spores, if they can be found, and a tube of the new silica glass which will stand stronger heating during the pumping, and thus make it possible to reach higher vacua.

THE WILDER PHYSICAL LABORATORY,
Dartmouth College, Hanover, N. H., April, 1903.

THE SUN-SPOT PERIOD AND THE VARIATIONS OF THE MEAN ANNUAL TEMPERATURE OF THE EARTH.[a]

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It has long been sought to discover if the various meteorological phenomena of the earth, and particularly the temperature, are subject to periodic variations other than the diurnal and annual periods depending on the rotation of the earth and its motion in the ecliptic. The astrologers of the middle ages, who affected to discern a relationship between the great climatological changes of the globe and the configuration of the sun and planets, and who based predictions upon such phenomena, may be considered perhaps as the pioneers in this line of study.

During the eighteenth and the first half of the nineteenth centuries men of science made numerous attempts to determine if meteorological phenomena were dependent on the relative positions of the sun and moon, and if consequently they could be associated with the various periods common between these heavenly bodies, such as the Draconic period, the Saros, and the period of nodes. These studies were influenced by a long-standing and still prevalent belief, profoundly fixed in the popular mind, that the moon exercises a preponderating influence upon terrestrial climates.

More modern and exact investigations have thoroughly tested this traditional belief, and while it is shown that the moon actually appears to produce tides in the higher regions of our atmosphere analogous to those of the ocean, it is on the other hand established that our satellite exercises no appreciable influence upon the temperature or climate of the earth, and investigations along these lines have been at length abandoned.

I.

The inquiry was brought upon a new field when, in 1852, Sabine, Wolf, and Gautier discovered that the phenomena of terrestrial magnetism were subject to variations of a period equal to that of the sun spots. A little later Fritz discovered the same period in the manifestations of the aurora borealis. Thenceforth it was natural to inquire if all the other meteorological phenomena were not equally subjected to the influences of sun spots. (We do not speak here of more or less serious attempts which have been made from time to time

[a] Translated from Revue Générale des Sciences, August, 1903, pp. 803–808.

to find relations between sun spots and the appearance of Asiatic cholera, famines, or commercial crises.)[a]

So far as concerns climatology almost the only result certainly established thus far, outside the question of temperature, is that derived by Meldrum,[b] director of the observatory on the island of Mauritius, who found the mean annual rainfall of the earth slightly greater in years of maxima than in those of minima of sun spots. The causes of this variation in rainfall are not yet understood, but I may incidentally remark that the views I have myself advanced in relation to the aurora borealis[c] may afford a simple explanation, for I have shown that during years of maximum sun spot frequency the Hertzian waves emanating from the sun induce the formation of the cathode rays of the aurora borealis more abundantly than in years of minimum sun spots. On the other hand, it is known that the propagation of cathode rays is favorable to the condensation of vapor; thus it follows that water vapor within the atmosphere, other conditions being equal, would condense more abundantly in the form of rain during years of maxima of sun spots, as found by Meldrum.

The idea that the sun spots should have some influence on terrestrial temperatures is very old. This view was advanced by Riccioli in 1651, shortly after the discovery of sun spots, but so little was known of the nature and magnitude of their influence down to recent times that in 1872 Wolf was still able to write: "The relation which Herschel supposed to exist between sun spots and the mean temperature of the earth is still in question."[d] It might seem at first sight strange that while the connection between the sun-spot period and terrestrial magnetism and aurora was established almost as soon as the question began to be investigated, the exact influence of sun spots on the temperature of the earth, although long suspected, had not been determined even as late as 1872. There are two kinds of causes contributing to this:

First. While the eleven-year variations of the Aurora Borealis and of the phenomena of terrestrial magnetism are so great as to be readily discernible in the amplitude of the phenomena in question, the effect on temperature is only a fraction of a degree centigrade, as we shall presently show, and thus of an order below that of the accidental and local variations of temperature.

Second. The researches published on this subject prior to 1872 gave but uncertain and contradictory results, because the authors did not

[a] This last idea is not perhaps absurd, for it is certain that if the sun spots really exercise a sensible influence upen terrestrial meteorology, they may indirectly influence harvests, as had been suggested by the great Herschel. But the price of grain depends quite as much, or even more, on political and social circumstances as upon meteorology.

[b] Monthly Notices of the Meteorological Society of Mauritius, December, 1878.

[c] Ch. Nordmann. Recherches sur le rôle des ondes hertziennes en Astronomie physique. Rev. Gén. des Sciences, 1er Avril 1902.

[d] Handbuch der Mathematik, Physik, Geodäsie und Astronomie, Vol. II, p. 302.

in general employ data other than those given by a single station, instead of employing the only rational method which could distinguish a general influence of solar origin from causes purely local and temporary, namely, the study of the contemporaneous records of numerous stations. Furthermore, the authors did not employ a sufficiently long period of observations, for these ought at the very least to extend over a complete sun-spot cycle. Some writers even ventured to draw conclusions from the observations continued only a few months at a single station. Finally, for the most part these early investigators studied the records of stations in the temperate zones, where, as Köppen has shown, the local and accidental variations are so great as to mask completely such minute changes of mean temperature as are here in question.

In 1873 there appeared the well-known memoir of Köppen, who concluded, from an able discussion of the thermometric observations at numerous stations during the period from 1820 to 1870, that the presence of sun spots was attended by a slight diminution of the terrestrial temperature.[a] Since the appearance of this memoir, which constituted the first trustworthy results reached in this direction, no extended work on the subject has been published.

II.

Encouraged by the friendly counsel of M. H. Poincaré, I have undertaken to continue the study of this important subject for the period 1870 to 1900, for it seemed to me very desirable to throw additional light, if possible, upon a point so important to physical astronomy and the physics of the earth.

The work of Köppen established that the curve of variation of mean annual temperature is reasonably regular only for tropical stations, and that in the regions exterior to the Tropics the curve of variation becomes so irregular that it is impossible to recognize in it any periodicity whatever. This result was perhaps to be expected, for the tropical regions are characterized by a very even climate, whereas for stations nearer the poles the accidental variations of temperature are very great, and indeed enormously greater than the slight variation of temperature which will be found below to attend the sunspot cycle.

Accordingly I have made use of thermometric observations from tropical stations exclusively in this study, but since the meteorological observations of the past thirty years have been greatly extended and systematized, I have been able to employ material much more extensive and trustworthy than was at Köppen's disposal. Thus the series of observations for separate stations are generally longer than he

[a] Köppen: Zeitschrift der österreichische Gesellschaft für Meteorologie, Vol. VIII, 1873, pp. 241, 273.

employed, so that while he was occasionally obliged to use series of no more extent than six years of observation, which could not fail to be a serious source of error, I have retained no series shorter than eleven years, corresponding to the mean period of the complete sun spot cycle. Furthermore, while Köppen had no observations from stations outside the Indies, the Antilles, and tropical America, I have been able to employ data from a greater number of stations, distributed more thoroughly over the globe, so that the result obtained can be considered as really representing the mean state of all that portion of the earth comprised within the Tropics. The stations for which I have used all the observations published since 1870 are:

Sierra Leone, Recife (or Pernambuco), Port au Prince, Trinité, Jamaica, Habana, Manila, Hongkong, Zi Ka Weï, Batavia, Bombay, Island of Rodriguez; Island of Mauritius.

For each station there has been computed the deviation of the mean temperature of each year from the general mean for a great number of years. Then for each year from 1870 to 1900 the general mean of the deviations of all the stations was obtained.

The following table contains the results thus derived. In the column headed "Sun spots," will be found for each year the relative number of sun spots according to Wolf; and the column headed "Deviations," gives in degrees centigrade the mean departure in temperature for all the stations as obtained in the following manner:

If a_1 represent the arithmetical mean of the deviations of temperature at all stations for a given year, a_0 that for the year preceding, and a_2 that for the year following, the number found in the column headed "Deviations" corresponding to the year in question is equal to

$$\frac{a_0+2a_1+a_2}{4}.$$

These numbers have been employed rather than the direct arithmetical mean for the given year, in order to give a more regular series by eliminating as well as possible the secondary irregularities.

TABLE I.—*Comparison of sun spots and temperatures, 1870 to 1900.*

Year.	Sun spots.	Deviations.	Year.	Sun spots.	Deviations.
		°C.			°C.
1870	[a]139	−[b]0.22	1886	25	− 0.17
1871	111	− .14	1887	13	− .21
1872	101	− .07	1888	7	+ .13
1873	66	− .09	1889	6	+ .15
1874	44	− .13	1890	7	+ .06
1875	17	− .12	1891	35	+ .04
1876	21	− .05	1892	73	− .05
1877	22	+ .08	1893	[a]84	−[b].12
1878	3	+ .13	1894	78	− .05
1879	6	+ .06	1895	64	+ .07
1880	32	+ .11	1896	41	+ .20
1881	54	+ .20	1897	26	+ .25
1882	59	+ .07	1898	26	+ .19
1883	[a]64	− .10	1899	12	+ .18
1884	63	−[b] .21	1900	9	+ .25
1885	52	− .21			

[a] Maximum. [b] Minimum.

Fig. 1 is a graphical representation of the results contained in the table. Ordinates of the curve of temperatures are taken directly from the column headed "Deviations," and plotted in the usual way, while the ordinates of the curve of sun spots are plotted with decreasing values toward the top of the sheet, so as to give a figure apparently the inverse of the sun-spot frequency.

It will be seen at once that the two curves run in a general way parallel.

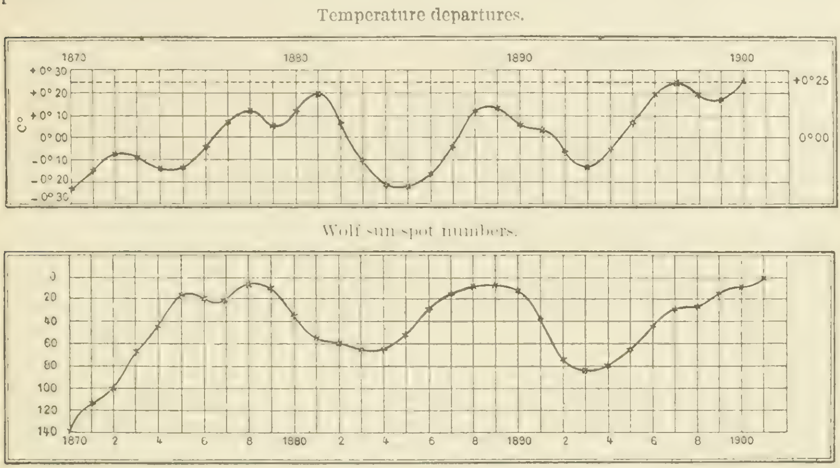


Fig. 1.—Comparison of sun spots and mean temperatures.

The following more careful discussion goes to show that their similarity extends even to minor details:

1. If we consider the dates of maxima and minima of temperature and sun spots, respectively, as found in the two curves, we may express the results in the form of a table as follows:

Table II.—*Maxima and minima of sun spots and temperatures.*

Minima of temperature.	Maxima of sun spots.	Maxima of temperature.	Minima of sun spots.
1870	1870		
		1881	1878
1884–85	1883		
		1889	1889
1893	1893		
		1900	1901

This comparison shows that the agreement between the times of minima of temperature and maxima of sun spots on the one hand and between maxima of temperature and minima of sun spots on the other is very satisfactory.

2. It is well known that the interval between a minimum of sun spots and the succeeding maximum is usually shorter than the interval between a maximum and the following minimum. The $2\frac{1}{2}$ sun-spot

periods from 1870 to 1900 were not exceptions to this rule, and it will be noted that the $2\frac{1}{2}$ corresponding temperature periods also conform to it, as appears in Table III.

TABLE III.—*Number of years elapsing between times of successive maxima and minima.*

	1 Max. sun spots.		2 Min. sun spots.		3 Max. sun spots.		4 Min. sun spots.		5 Max. sun spots.		6 Min. sun spots.
Sun spots		8		5		6		4		8	
Temperatures		11		3.5		4.5		4		7	
	Min. temp. 1		Max. temp. 2		Min. temp. 3		Max. temp. 4		Min. temp. 5		Max. temp. 6

For both sun spots and temperatures we find:

Interval 2–3 less than 3–4, and 4–5 less than 5–6.

Moreover, for both temperatures and sun spots the intervals 2–3 and 4–5 are smaller than any of the intervals 1–2, 3–4 and 5–6, despite the inequality of the total periods embraced in the two and one-half cycles considered. These include the half period of eight years (1870 to 1878), a full period of eleven years (1878 to 1889), and a second full period of twelve years (1889 to 1901).

3. Again, designating as "rich in sun spots" the years for which the Wolf relative numbers exceed 60, and as "poor in sun spots" those years in which they fall below 15, we may form the following table, in which the temperature variations are divided between the classes so defined:

TABLE IV.

Years rich in sun spots.		Years poor in sun spots.	
Year.	Temperature deviations.	Year.	Temperature deviations.
	°C.		°C.
1870	−0.22	1878	+0.13
1871	− .14	1879	+ .16
1872	− .07	1887	− .05
1873	.09	1888	+ .13
1883	− .10	1889	+ .15
1884	− .21	1890	+ .06
1892	− .05	1899	+ .18
1893	− .12	1900	+ .25
1894	− .05		
1895	− .07		
Mean	− .10	Mean	+ .11

This comparison also exhibits a satisfactory accord between the two kinds of phenomena.

4. Let us now consider the years of maxima and minima of sun spots, and for each of these years calculate a "smoothed" sun spot number by taking the mean between the number for the given year and the half sum of the numbers for the years next preceding and next following, respectively. We proceed similarly with the temperature deviations, thus treating both kinds of data in a way to eliminate secondary influences, while leaving a preponderating importance with

the year in question. For brevity denote the resulting temperature deviations by $\delta\theta$ and the sun-spot numbers by δS. We thus obtain Table V.

TABLE V.—*Maxima and minima of sun spots.*

Year.	Maxima.		Year.	Minima.	
	$\delta\theta$.	δS.		$\delta\theta$.	δS.
	°C.			°C.	
1870	−0.19	129	1878	+0.10	9
1883	− .08	63	1889	+ .12	7
1893	− .08	80	1900	+ .21	5
Mean	− .12		Mean	+ .14	

Comparing the values of δS with the numerical values of $\delta\theta$, it appears that they vary in general in the same sense for years of maxima of sun spots, and in opposite senses for years of minima. But if we regard algebraical signs, a maximum maximorum of δS corresponds to a minimum minimorum of $\delta\theta$, and vice versa.

5. Finally, the principal points of the preceding discussion may be implicitly summed up as follows:

The function of temperature departures which we have just considered may be referred to a new origin of ordinates such that the departure $+0^\circ.25$ becomes the new zero; and we may reckon the new ordinates in the direction which was formerly that of increasing negative departures. Denoting by $\delta\theta$ the new ordinates as thus considered, it will be seen that $\delta\theta$ represents in some sort (other things being equal) the difference for each year between the temperature which would have been experienced if there had been no sun spots, and that which was experienced in reality; for the origin of ordinates at $+0^\circ.25$ corresponds with the conditions of the year 1900 when there were scarcely any sun spots. If now we take the mean of the values of $\delta\theta$ for the first half period 1870 to 1881, and multiply this mean by the number of years in this half period, and deal similarly by the periods 1881 to 1889, and 1889 to 1900, also treating the sun spot frequency data δS after a similar fashion, the results obtained are expressed by the following table.[a]

TABLE VI.—*Summation of the temperature curves and of the inverse sun-spot frequency curves.*

Period.	$\sum_{t_2}^{t_1}\delta\theta$	$\sum_{t_2}^{t_1}\delta S$	$\dfrac{\sum_{t_2}^{t_1}\delta S}{\sum_{t_2}^{t_1}\delta\theta}$
$\left.\begin{matrix}t_1=1870\\ t_2=1881\end{matrix}\right\}$ ½ period of θ	297	567	0.52
$\left.\begin{matrix}t_1=1881\\ t_2=1889\end{matrix}\right\}$ 1 period of θ	216	492	.44
$\left.\begin{matrix}t_1=1889\\ t_2=1900\end{matrix}\right\}$ 1 period of θ	167	300	.55
Mean			0.5 ± 0.06

[a] The unit of temperatures for this table is the hundredth of a degree centigrade.

It apppears that $\frac{\sum_{t_2}^{t_1} \delta S}{\sum_{t_2}^{t_1} \delta \theta} = 0.5 \pm 0.06$. There seems to be a remarkably constant proportionality between the total number of sun spots and the summation of the temperature departures for all of the periods reviewed.

6. From the result just given it seems to follow that we may assign to the arbitrary sun-spot frequency numbers of Wolf a physical significance expressing the mean relation between sun-spot frequency and terrestrial temperatures. Thus 1 Wolf number corresponds to $0^\circ.01 \times 0.5 = 0^\circ.005$ C.

Finally, from this discussion we are able to state definitely the following law, which is also in agreement with the results of Köppen:

The mean terrestrial temperature is subject to a period identical with that of sun-spot frequency, and the effect of the presence of sun spots is to diminish the mean temperature of the earth, so that the curve of mean temperature departures runs parallel with an inverted curve of sun-spot frequency.[a]

III.

It may now be inquired how far the result just reached might be theoretically predicted. It is known that sun spots radiate less than equal surfaces of the adjoining photosphere. This may be visually observed from a comparative study of sun-spot and photospheric spectra, which indicates a strong general absorption over the sun spots. It has also been shown by the bolometric observations of Langley, who reached the result that the umbra of an average spot emitted only 54 per cent as much radiation as equal areas of the adjacent photosphere. Again, at the time of maximum sun spots the thickness of the absorbing layer of the chromosphere is increased, which tends to diminish the radiation of the sun. Still, there are also present at this time many faculæ which radiate more strongly than other portions of the photosphere. The effect of the faculæ tends to offset the absorption of the more opaque chromosphere, and we may assume as a first approximation that the two effects compensate each other, leaving only the influence of sun spots themselves to consider.

From the researches of Zenker,[b] based upon several different methods yielding concordant results, the mean temperature of the earth's sur-

[a] This law has been deduced from the discussion of observations made exclusively at tropical stations, for these alone present a sufficient regularity of climate to permit of the detection of such small temperature variations as are here in question. But it would seem to be legitimate to extend the application of the law to the whole surface of the globe, for it is impossible to conceive that a variation of the solar radiation could influence temperature over half the surface of the earth without affecting the remainder.

[b] Thermische Aufbau der Klimat. Halle (Leipzig), 1895.

face would be $-73°$ C.[a] if the solar radiation did not exist. Now, the actual mean temperature of the earth is about $+15°$ C.,[b] from which it follows that the effect of solar radiation is to raise the mean temperature of the earth 88° C. above the temperature of space.

The mean area covered by sun spots during a year of maximum activity may be taken as not far from one one-hundredth of the total area of the sun's disk. From this it follows that the radiation is diminished by the presence of sun spots by about one two-hundredth, and this should produce a diminution of terrestrial temperature of about $\frac{88}{200}°$ or 0°.44 C.

This, it will be remembered, is almost exactly the result obtained above from the discussion of direct observations as representing the excess of mean terrestrial temperature during the years of minimum over those of maximum sun spot activity.[c]

[a] [Note by translator.] Professor Poynting gives the temperature of space at $-263°$ C. See Phil. Trans. of the Royal Society of London, Series A, vol. 202, p. 529, 1903.

[b] Hann: Klimatologie. Stuttgart, 1897.

[c] I desire to express here my thanks to M. Mascart, who has been so good as to place at my disposal for this investigation the library of the Bureau Central meteorologique, and to M. Angot, who has given me most valuable counsel.

[NOTE BY TRANSLATOR.] The author's discussion of temperature departures in connection with the sun-spot cycle has aroused considerable interest among meteorologists. It is fair to say that while expert opinion is not entirely in accord with him in his methods of study and conclusions, the criticism which has been called forth by his paper seems to indicate that meteorologists require further evidence rather than that they wholly disbelieve in the alleged association of sun spots and temperatures.

Professor Angot, in an article translated for the Monthly Weather Review of August, 1903 (p. 371), strongly objects to Nordmann's procedure of smoothing the yearly temperature departures and combining observations from numerous stations, on the grounds of uncertainty of the real mean temperatures of some stations, and of the prejudicial effect upon the general mean of unequal lengths of the series of observations at the several stations. He prefers to treat each station separately, and gives reductions of data from Guadaloupe, Hongkong, Batavia, Bombay, Barbados, and Habana, extending over periods ranging from ten to fifty years, and embracing 16 sun-spot periods altogether. Fourteen of these periods yield results in the same general direction as those obtained by Nordmann, and 2 in the contrary, so that Professor Angot remarks that "the probability is, then, according to these observations, 7 to 1, that an increase in the number of sun spots is accompanied by a diminution in the temperature." It appears from his reductions that "an increase of 100 in Wolf's relative sun-spot numbers (a difference which frequently exists between a maximum and a minimum) will be accompanied by a diminution of 0°.33 C. in the value of the mean annual temperature." Professor Angot concludes: "It is evident that in order to determine the value [of the temperature departure for an increase of 100 sun-spot numbers] it would be necessary to work with a much larger number of series. I have given the numbers which precede only as an example of a method which appears to me more exact and more convincing than that ordinarily employed."

Professor Abbe, commenting editorially on the articles of Nordmann and Angot (Monthly Weather Review, October and December, 1903), refers to a discussion of

the observations at Hohenpeissenberg, extending from 1792 to 1850, which he himself published in 1870. This discussion yielded the result that an increase of 100 Wolf numbers in the sun-spot frequency was attended on the average by a decrease of about 1° C. in the mean annual temperature for this station. He refers also to Köppen's extensive investigation, which yielded the result that an increase of 100 sun-spot numbers was attended with a decrease of temperature of 0°.54 C. for equatorial stations, but with more complex effects for stations in temperate latitudes. But while this statistical evidence thus tends chiefly in the same direction, Professor Abbe is not convinced that we can certainly ascribe this apparent temperature periodicity to solar influences. He says that although for a long time he "believed that it might be possible to establish an intimate connection between solar radiation and solar spots, yet the steady development of our knowledge of the selective absorption of the earth's atmosphere has shown that we can not argue by crude statistical methods from terrestrial temperatures up to solar radiation. We may speak of periods and variations in our temperatures, but these do not demonstrate a similar period in the solar temperatures or solar radiations, since unsuspected periodic variations in the constituents of the earth's atmosphere may be the cause of the variations we should otherwise attribute to the sun itself. * * * The mere fact that there is a decrease of temperature in the Tropics at sun-spot maximum argues nothing as to the direct relation of cause and effect between the two phenomena. I have on hand a collection of monthly charts of temperature departures for the whole globe for several successive years, which tend to show clearly that the sun-spot period in the earth's temperature is a purely local, terrestrial matter, moving round from one part of the world to another, just as do our droughts and our rains, our barometric waves and our cold waves; analogous to the movement of an earthquake wave over the ocean, going sometimes rapidly and sometimes slowly, reflected from a continent, exaggerated in some arm of the ocean, breaking in waves on a shore, but scarcely felt on an island in midocean, and finally dying out by virtue of innumerable interruptions, as all forced waves must do unless they happen to be reenforced by a process similar to that of resonance in sound waves."

A word may be added in connection with Nordmann's discussion of the direct effect of sun spots on temperature, which the diminished radiation of sun spots as compared with the photosphere would lead us to expect. Substantially the same argument, based on Newton's law of cooling, was published by Professor Langley in 1876 (see Monthly Notices British Astronomical Society, November, 1876), and he reached the conclusion that the presence of sun spots in a period of maximum solar activity might reduce the mean temperature of the earth not exceeding 0°.29 C. by their direct effect in diminishing solar radiation, but he did not decide whether terrestrial temperature may not be quite otherwise affected by some varying solar action of which spots are merely accompaniments.

Within the last twenty years it has been shown that Newton's law of cooling does not apply to bodies losing heat solely by radiation, and it has been experimentally verified that, in accordance with Stefan's law, the perfect radiator or so-called "absolutely black body" emits an amount of radiation proportional to the fourth power of its temperature above absolute zero. All other bodies radiating by virtue of their temperature emit less than the perfect radiator at any given temperature, but at low temperatures imperfect radiators are found to depart from Stefan's law and to emit amounts more nearly proportional to the fifth power of their temperature. Since the earth is losing heat almost solely by radiation and is kept at substantially a constant mean temperature of about 290° absolute by the solar rays, the earth's total radiation is proportional to $(290)^{4+}$ and is equal to that received from the sun if we neglect the small amount received from space. If now the sun's radiation were reduced by $\frac{1}{200}$, as supposed by the author, on account of the presence of sun spots,

the earth would, if allowed sufficient time, take up a new mean temperature T such that $(T)^{4+}=\frac{199}{200}(290)^{4+}$ or $T=290°\left(\frac{199}{200}\right)^{\frac{1}{4+}}$. Thus T would be equal to or exceeding 289°.97, and the fall of temperature directly due to the sun spots would be only 0°.03 or less. This line of argument is substantially that adopted by Professor Poynting, Philosophical Transactions, Series A, vol. 202, p. 530, 1903.

It would therefore appear that the direct effect of sun spots is far smaller than that observed by Nordmann. But it is entirely possible that the increased absorption of the sun's envelope, which he mentions as probably attending them, may produce the effects found. See in this connection Halm's article, "A New Solar Theory," Smithsonian Report, 1902, and also S. P. Langley, Astrophysical Journal, June, 1904.

METHODS OF FORECASTING THE WEATHER.[a]

By Prof. J. M. PERNTER.

Allow me to-day to address you once again on the subject of weather prophets, and this time to bring before you not only one or two kinds of weather forecasting, but to give you a more general survey of all methods at present in use, be they right or wrong, with or without results. I will keep strictly to the title of this lecture and give the prominent place to the methods of forecasting. I shall explain them and subject them to critical analysis, naming at the same time the advocates of each of the various methods; in the technical investigation, we have to do with the value of the methods and not that of the persons. I must, however, at once bring prominently forward the fact that we have at present, unfortunately, no method by which we can forecast the weather with absolute certainty even for one day in advance, to say nothing of longer periods. This is already self-evident from the fact that we are now able to speak of many methods of forecasting, whereas if there were a sure and infallible method, then it would be out of place to speak of the other methods to this society for the advancement of scientific knowledge.

All methods of weather forecasting, not excepting those in use by the central meteorological offices, are based upon observed weather conditions, and have, therefore, an empirical foundation. Many of them do not even make the slightest attempt to put their methods on a theoretical basis and content themselves with setting up "weather rules." Even the scientific methods of professional meteorologists have not yet succeeded in deducing a theory capable of determining in advance the changes of the weather as the effect of one or several known causes. Only the advocates of the influence of the moon have ventured solely by means of aprioristic theories to "calculate" the weather for long periods in advance.

[a] A lecture delivered by Prof. Dr. J. M. Pernter to the Association for the Advancement of Scientific Knowledge, Vienna, January 14, 1903. Translated from the Vorträge des Vereines zur Verbreitung naturwissenschaftlicher Kenntnisse in Wien. 43d Jahrgang, Heft 14. Printed in Monthly Weather Review, U. S. Department of Agriculture, December, 1903.

There are many widely different methods by which the various classes and kinds of weather prophets carry on the work of weather forecasting. There are those who make use of the behavior of animals to foretell the weather; hunters who recognize the character of the approaching season from the actions of the wild animals; the observers of birds, spiders, crickets, ants, and other animals, from whose conduct they judge of the approaching weather. But in addition to this class which utilizes living animals there is another opposing class that prefers to make use of the dead substances of the animal or vegetable kingdoms, such as hairs, strings of instruments, roots and fibers of plants; by means of their expansions or contractions, either with the aid of little weather houses and figures or without them, they recognize the coming weather. Others prefer to consult stones and walls as to the character of the weather to be expected, and turn rather to inorganic nature in order to learn from the "sweating" or dryness of these whether to expect rain or continued fine weather. Thus, as you see, all the kingdoms of nature are drawn upon to furnish prognostics of the weather, and it may depend upon the occupations and predilections of the various persons interested in the coming weather whether they give the preference to one or the other. But I had almost forgotten to mention another class—perhaps the largest—those who are not to be satisfied by any one of the three kingdoms nor even by all three together, and who rely only on their own bodies for foretelling the weather—assuming, of course, that these have nerves, joints, and corns. Sometimes it is the stomach and sometimes even the head that is made use of. I am not joking in the least; on the contrary, the persons inclined to this kind of weather forecasting excite my sincere commiseration.

If these classes of weather prophets who undertake to foretell the weather by the sensations of their bodies, by observations of the animal and vegetable kingdoms, and even by the processes of inorganic nature, always rely upon facts which may have a distant connection with the weather, yet they are still far behind that class which forms its conclusions of the approaching weather from observations of the weather conditions themselves. You are all well acquainted with this latter class of weather prophets. In every community there is at least one person who is especially relied upon, whether he be a farmer, a miller, a teacher, or a pastor of long standing. They look up at the sky, observe the clouds and the direction of their motion, and from these they forecast the weather for the next day, with good results. These local weather prophets rely indeed upon phenomena which have the closest connection with the coming weather. For the weather does not spring like a Deus ex Machina down from a distant cuckoo's nest in the clouds, but is drawn from comparatively near regions, or, if you prefer, forms gradually in the place itself. This coming, this

formation of the weather, is announced by the appearance of the sky, sometimes for a longer, sometimes for a shorter time in advance, and the skill of the weather prophet consists in rightly interpreting, for the near future, the appearance of the sky and the weather conditions. Since it is generally necessary in order to grasp the weather conditions correctly, to have a clear judgment founded on long experience in observing, together with an accurate eye, and, I might almost say, an inborn quickness of perception, therefore there are as a rule only single individuals in every community who enjoy the reputation of being good weather prophets. Certain phenomena, however, are of so typical a nature that they have been reduced to fixed rules and are everywhere expressed in popular language.

Thus every country has its weather signs; if the clouds are increasing, a storm or continuous bad weather is approaching. In every locality there is one direction of cloud motion that betokens bad weather, and another, generally the opposite direction, which portends fine weather, etc. Weather rules relative to the red morning and evening sky have been deduced. The rules that bad weather is expected when in any given locality the summit of a certain mountain is covered with a cap; that a small "watery" halo around the moon indicates rain; that the weather will continue bad if, when the clouds break up, a second light covering of clouds is seen above them; that it will be fine weather if, after rainy weather, according to the locality, a certain wind sets in; that a slow breaking up of the clouds gives promise of fine weather, etc.; all of these rules have been formulated from long-continued and accurate observation, and are exceedingly well adapted for local weather forecasts from one day to the next. Experienced observers also know from the color and nature of the clouds whether the prevailing weather, notwithstanding otherwise favorable indications, will continue or will change, and by these delicate distinctions they generally acquire the reputation of being especially good weather prophets.

These observations of weather signs led the way, however, to more far-reaching rules which included the attempt to determine from the weather conditions at a certain season of the year what they would be for a long series of days; or, to determine from the weather of a season, or of a certain day, or a fraction of a day, the conditions of an approaching season. Thus originated the so-called "farmer's rules," among which are some valuable ones based upon good observations extending over a hundred years, but in contrast to these there are, unfortunately, many poor ones for which we are indebted to the superficial and frivolous rules manufactured by speculating calendar makers.

Others, however, went still further and, from observing that the weather of one year resembled that of a former year, concluded that

there is a certain regularity in the recurrence of years with similar characteristics, and that they were justified in enunciating the law that almost exactly the same weather returns at intervals of eleven, or of eighteen, or nineteen years, so that it would only be necessary to expect in the coming year the weather observed a certain number of years before. It is evident that this would be the simplest method for predicting the weather in any year, day by day, or at least week by week, and this is the system followed in the so-called "hundred-year calendar." Unfortunately the facts do not agree with the predictions.

Both the methods above named in general endeavor to keep one free from preconceived ideas as to causes, and base their predictions of the weather only upon earlier observations and experience, often supported by records of the weather actually prevailing, whether made with or without instruments. There are other prophets who have sought for the cause that dominates the weather and weather changes and adopting this when found have made their weather predictions in accordance with the properties, movements, and changes of this accepted cause.

This latter class, somewhat precipitately and without sufficient experience in the principles of observational work, but driven by the innate longing in the human breast to seek for a cause for all matters and supported only by general a priori considerations has sought for the dominating cause of the weather. Thus, from the consideration that the sun dominates everything on the earth, Professor Zenger has chosen that as the agent of the weather changes, which he ascribes to the rotation of the sun on its axis. Now, since the time required for a revolution of the sun occupies about twenty-six days, he has chosen one-half of the time of a revolution, that is to say twelve to thirteen days, as the period by which he measures the changes of the weather, and has arranged a weather calendar according to which there is a day of disturbance every twelve to thirteen days. In the interval between the two days of disturbance there is an interval of safety, or what he calls "calms." The comparison of the predictions of the "days of disturbance" and "days of calms" with the weather actually occurring is supposed to give the proof of the correctness of the assumption that the semirotation of the sun governs the weather. Up to the present time, however, this has not yet been accomplished, for the attempted demonstration has entirely failed.

The method of weather predictions proposed by Professor Servus is of a similar character; he considers the interior of the earth, and from the fact that the attraction of the earth upon the atmosphere attaches the latter to the earth, he argues that "all the great disturbances in the equilibrium of our atmosphere are caused by changes in the condition of the interior of the earth, which produce disturbances

in the power of attraction." You will see at once without further explanation that this is not a tenable principle for weather predictions. Servus himself, for the purpose of preparing weather predictions, has been obliged to call in the sun and moon to his aid as causes of the disturbance in the condition of the interior of the earth. In this way his method approaches so nearly to that of Zenger and those of the lunar prophets that we need not treat of it separately.

But Professor Lamprecht has shown us in a most startling manner how far one may be led away by adopting a priori causes for the changes of weather without a sufficient basis of experience. By analyzing a series of observations for several years he has discovered five periods in weather processes, one of $12\frac{1}{9}$ days, one of $12\frac{2}{3}\frac{3}{0}$ days, one of $13\frac{9}{11}$ days, one of $14\frac{3}{4}$ days, and one of $29\frac{3}{7}$ days. Before passing on I must just tell you that one can, according to his method, compute periods of almost any length desired. This is not objectionable; but he now proceeds immediately to find the causes for these periods, which were really only computed and not at all furnished by experience, and, since he sincerely wished it, he found them. We can only be astonished at the boldness of his hypothesis. He assumes the earth to be surrounded by five rings, similar to the rings of Saturn, and that their periods of rotation and temporary relations to one another are the causes of his weather periods. Lamprecht represented to himself the existence of these imaginary rings in such a manner that he immediately endowed the rings with names, giving them successively the following magnificent names: Emperor William ring, Moltke ring, Bismarck ring, Copernicus ring, King Albert ring.

An old and by far the most widespread method of weather prediction is based on the idea, which is I might say universal among mankind,[a] that the heavenly bodies have an influence on everything which takes place on the earth, and particularly upon the weather. The moon is that one which was supposed to more especially influence the weather, although this power was attributed to the planets also, so that each one produces a certain kind of weather, and therefore divides the year into damp, dry, stormy, quiet periods, etc., according as one or the other planet is the "ruler for the year." The moon is credited with the principal dominator of the changes of the weather. The weather is supposed to change by preference with the moon; therefore the new moon and the full moon especially possess the power of influencing the weather, and one of the most widely spread weather rules is that the weather changes with the new moon and the

[a] Astrology seems to have been specially cultivated in Mesopotamia and to have been spread north, south, and west by Sanskrit, Greek, and Arab influences. It is peculiarly Asiatic and European. There is no record of its having had any great influence among the Chinese, Malays, or American Indians. It can, therefore, hardly be spoken of as universal among mankind.—Ed.

full moon. However, the first and last quarters are considered of greatest importance by a great many. Especially clever observers of the influence of the moon upon the weather pretend to have also observed the distinctive individual influences of the phases known as octants. In general the opinion is very widespread that the decreasing moon exercises a weak and the increasing moon a strong influence. Thus far the theory of the influence of the moon on the weather is the direct result of the popular belief in the moon, without regard to any scientific basis.

I am not able to state whether the growth of this popular belief was preceded by observations of the weather changes, and is therefore to be regarded as a result of observations (it is not a question here as to whether the latter were defective and inconclusive or not), or whether, on the contrary, the belief in the influence of the heavenly bodies and in that of the one which, after the sun, appears the largest and most striking to mankind, namely, the moon, was the earliest step, and that it was in the light of this belief that observations were first made. At all events, the latter is far more probable than the former, and therefore I can not put the moon theory of weather predictions in the same category as the methods mentioned in preceding paragraphs. These latter methods were certainly based on observations (we say nothing as to whether the observations were correct or not); but this is not established in regard to the belief in the moon theory; indeed, the probability is in favor of the contrary process, namely, the opinion that the moon must influence the weather came first, and observations only came later in order to see if the theory were correct.

This idea is strongly supported by the more recent development of the theory of the influence of the moon upon the weather. This newest and at the present time very prominent phase of this theory did not start by collecting reliable observational data and deducing from these observations the influence of the moon upon the weather, but first adopted the old belief in the moon and then sought to create for it a scientific basis by means of a priori assumptions and even theoretical mathematical explanations.

With these results, either assumed or computed, the representative of the modernized theory of the moon appears before the public and invites his contemporaries to test his "results" by observation. This process is, as you see, the exact opposite to that of the true empirical method. The empiricist makes observations, observes long and much, and sums up the general results of the observations in certain propositions or "rules," and when it is possible draws his conclusions as to the cause of the phenomena. The modern moon prophets turn the process upside down. They designate the moon beforehand as the cause of the changes of the weather; from the various positions of the

moon with respect to the earth and the sun, with the assistance of the laws of attraction—without any strict investigation as to how far these can possibly be of influence—they compute the attraction exercised by the moon in its separate positions, and say on such and such a day the influence of the moon must have produced such and such a result on the weather. The confirmation of these predictions by the observations should then only show the accuracy of their assumptions and computations. The number of these modern moon prophets is at present large. Many of them take into consideration the planets in addition to the moon. The names of the most prominent advocates of these moon theories are known to you. They are as follows: Falb, Ledochowski, Gladbach, Demtschinski, Garigou-Lagrange, A. Poincaré—not the celebrated mathematician—and Digby.

It would be quite erroneous if this method of investigation into the causes of the weather were regarded as incorrect and improper. By this presentation of the subject I wish only to show that the modern moon prophets—and probably also the older ones—have not introduced strictly inductive empirical methods into their belief in the moon, but that this belief was there from the first and that they have made use of the discovery method for its confirmation, since it is on the basis of the moon theory, or, if you prefer, of aprioristic considerations as to the influence of the moon, that they make their weather predictions, and then from the agreement between these they endeavor to deduce the correctness of their assumptions. Against this method as such there is nothing to be said, but it demands the most conscientious, straightforward, logical, and accurate determination of the consequent weather if we wish by this method to arrive at a confirmation or refutation of the propositions advanced as to the influence of the moon. How this is to be managed we have still to learn; meanwhile it is at present only necessary, in this enumeration of the various methods for predicting the weather, to include that one which represents the influence of the moon.

As soon as men began to observe the barometer attentively, they began gradually to recognize that the rising and falling of the barometer had an evident connection with the weather. It was the celebrated burgomaster, Otto von Guericke, of Magdeburg, who first used the barometer as a "weather glass." He applied, even then, to his water barometer the "weather scale" which is at present in such general use, on which the highest reading occurring at any place is designated as "fine weather," the lowest reading as "rain and wind," etc. The barometer as a weather glass has taken its course throughout the world, and is to-day used almost universally. After the introduction of the aneroid barometer the "weather scale" was also affixed to that, and whoever purchases such an instrument pays particular attention to

make sure that the weather scale is correctly fixed on it. The makers of these instruments must know the mean pressure at the dwelling place of the purchaser; there they place the term "changeable;" the point where the pressure is about 10 millimeters above the mean is "fine," and at about 20 millimeters above the point designated as "changeable" will be "steady," "fine," or "dry," or the like. At about the same distance below "changeable" is placed "rain" and "storm."

Whoever has provided himself with an instrument of this kind believes himself to be the possessor of a self-registering weather prophet and is generally highly indignant if it rains when his barometer stands at "fine," or astonished if it is fine weather when the barometer says "rain." Since these erroneous indications are not unusual with the barometer, therefore faith in it as an indicator of the weather is very much diminished, and is only maintained at all, on the one hand, by the fact that the barometer frequently "indicates correctly," and, on the other hand, by force of habit. Frequently, however, one has taken refuge in another instrument, namely, the hygrometer. This instrument shows only the amount of moisture actually prevailing in the air, in the same way that the barometer indicates the actually prevailing pressure. As the pressure and the moisture are both connected with the weather, the hygrometer may be used as a weather prophet in the same way as the barometer, although that is not its real vocation. If the hygrometer shows a high degree of moisture, that only indicates that the air is just then very moist, and this generally happens only when the weather is already bad. However, it happens sometimes that the moisture in the air increases while the weather is still fine, so that the hygrometer then indicates approaching bad weather. In the same way, the hygrometer will generally indicate dryness when the weather is fine; it will sometimes, however, when the weather is not yet fine, point to decreasing moisture, and thereby foretell approaching drier and finer weather. The best of these hygrometers are made of human hairs, divested of grease, which have the property of being expanded by dampness and contracted by dryness in a most admirable manner. This property of varying its dimensions with the changing moisture is also possessed by other animal and vegetable substances. There are a number of weather indicators of this kind, among which the little house with the little man and woman, in which the man goes out in bad weather and the woman in fine weather, is probably the best known.

The discredit into which the hygrometer as a weather prophet has often fallen is as easily understood as in the case of the barometer. Its duty is only to show the moisture actually prevailing at its locality, and this knowledge does not enable one to make determinations of the approaching weather any more accurately than does a knowledge of the pressure at any place.

A new, and we must at once say a truly empirical method of weather prediction, is that at present in use by all the official central meteorological establishments in the world. This method has gradually and slowly developed according to the exact rules of investigation in scientific practical meteorology, and is still far from having reached perfection. It has developed entirely, without any addition of an a priori nature, out of the observations of the weather processes, and is therefore based entirely upon well-established observational data. The most fundamental of these facts is that the weather is associated with the distribution of atmospheric pressure. It has been recognized more and more clearly by experience that the weather is determined not by pressure as shown by the barometer at the place of observation, but by the barometric conditions that prevail over vast regions; for instance, those distributed over the whole of Europe. Therefore one must chart and study the distribution of atmospheric pressure over the whole of Europe if one wishes to understand the weather actually prevailing.

It was necessary, first of all, to determine by extended observations, made as nearly simultaneous as possible, the distribution of atmospheric pressure for a definite hour, in order to perceive to what kind of weather this distribution of atmospheric pressure corresponded. It was by this means demonstrated that there is an extraordinarily great variety of forms of atmospheric pressure distribution; that these, however, can be classified into a certain number of types by having regard to the form as well as to the weather conditions given in these forms. * * * The thorough and persevering study of the weather that prevails on the occurrence of each type has led to the definite and certain recognition of the following theorems:

1. The weather, in all its details, depends upon the distribution of atmospheric pressure, and the same weather always corresponds to the same location relative to this distribution.

2. The weather of any place is, therefore, determined by its position in and relation to the various styles of pressure distribution.

3. If we succeed in knowing in advance what distribution of atmospheric pressure will prevail on a certain day or on a series of successive days or a longer season, then the weather of the day or of the period of time is thereby determined in advance.

4. The modifications introduced by reason of geographical conditions, the configuration of the ground—as, for example, the location of a place in the Alps, etc.—are constant for the location in each style of pressure distribution.

By means of these theorems, which were deduced from exact observations, the foundation was laid for a careful method of weather prediction. Two things were now necessary: (*a*) The perfecting of our knowledge of the typical distributions of atmospheric pressure and of

the details of the weather attending them; (*b*) the deduction of the rules, according to which one form of distribution of pressure either remains stationary, or moves over Europe, or changes into another form, or is pushed aside by some other type.

It is in the nature of things that the first task is more easily accomplished than the second. The present state of the art of weather prediction in our central meteorological institutes corresponds to this condition of affairs. The details of the weather conditions within the various styles of pressure distribution are, on the whole, quite well known. However, there remains much to be done in this direction, and it is now one of the most important duties of meteorology to most thoroughly investigate, in all directions and details, the distribution of the weather according to the forms of pressure distribution. The knowledge of the weather conditions for every place and for every type of pressure distribution offers the only entirely satisfactory empirical basis for weather predictions; moreover, it is by this knowledge alone that we can hope at some time to discover the fundamental laws of the changes in the weather. This knowledge, however, does not lead us immediately to a prediction of the approaching weather, but only teaches us to know the weather of one particular place when the distribution of pressure is known. In order to be able to predict the weather, we must know one thing more—we must know in advance what distribution of atmospheric pressure will prevail at the time for which we are predicting the weather. This foreknowledge of the pressure distribution is the starting point upon which the whole weather forecast depends. If this foreknowledge of the future distribution of atmospheric pressure is impossible, then weather prediction is impossible; if we can foretell it approximately, then a weather prediction of greater or less probability is possible, and we shall be able to make a larger number of correct than of incorrect predictions; if the distribution of atmospheric pressure can be known in advance with certainty, then we shall be able to make weather predictions with certainty.

Now, how do we stand as to the question of certainty in foreseeing the approaching distribution of atmospheric pressure? If we knew the laws according to which one distribution of atmospheric pressure changes over into another, or according to which it moves across Europe, as well as the laws that cause one distribution of atmospheric pressure to continue stationary or suddenly break up and another one result from it, then the problem could be solved and future weather could be predicted with entire certainty. We should proceed with mathematical accuracy in the prediction of weather, and be able to attain the correctness of the astronomers in their predictions of celestial planetary motions and phenomena. This, of course, is the ultimate aim of meteorological science, but we are at present so far removed from it that we have many well-founded doubts as to whether this object will ever be attained. Up to the present time we are only able

to deduce from the experience hitherto acquired a few empirical laws of limited applicability, according to which the types of distribution of atmospheric pressure remain stationary, change, or transform themselves entirely, or perhaps move away over the earth; even this limited empirical knowledge relates almost entirely to the change from one day to the next. Since these empirical laws as to the changes in the distribution of atmospheric pressure are so defective the difficulty of foreseeing the approaching distribution of pressure is correspondingly great, and the prediction of the weather even for the next day is proportionately unreliable. Since we have to do only with theorems founded entirely upon experience, the persons best qualified to make the predictions are those who through long years of practice have collected the most theorems as to the variations in the forms of pressure distribution, and have also learned by practice the many modifications to which these theorems are subject. In the forecasts for the next day men of much experience attain to more than 80 verifications in a total of 100 predictions; but the prediction of the distribution of pressure for more than one day in advance has such a low probability that in a forecast of the weather for several days in advance we must expect more failures than results.

You will say: "It is despairingly little that we have to expect from scientific weather predictions, and hence it is not to be wondered at that the public generally clamors for methods that promise more." It is easy to promise, but one's promise must be kept, and that is difficult. It would also be easy for scientific meteorologists to make the same promises and boastings as the other weather prophets, but they would then cease to be called scientific. And of what use is it to cling to those weather prophets who certainly promise a great deal, but finally leave you in the lurch? Of the popular methods of predicting the weather above enumerated, none accomplish nearly as much as is accomplished at present by the scientific method; indeed, very often they accomplish nothing beyond the noise they make in praising themselves. However, before I begin to criticise the various methods, I will briefly lay before you the processes adopted in weather prediction at the central meteorological stations. You know that at our central office in Vienna, for example, telegrams arrive every morning from more than 140 places over the whole of Europe; these telegrams contain the observations made that morning of pressure, temperature, moisture, precipitation, and wind. According to these telegrams the chart of the distribution of atmospheric pressure is drawn as it prevailed over Europe that morning; and from this particular style of distribution of atmospheric pressure in conjunction with that which prevailed on the preceding day, and by making use of the above-mentioned empirical laws governing the changes in the forms of the pressure areas, a tracing is made of the probable areas of atmospheric

pressure for the next day. When this sketch is completed then the predictions for the various portions of the kingdom are made upon the basis of our knowledge of the weather conditions at different points of each area of atmospheric pressure. Thus the primary difficulty consists in forming a correct conception of the pressure distribution for the next day, based on that prevailing on the morning of the day in question, and at the same time a clear idea as to the velocity with which the changes will proceed. In order to facilitate this difficult task the central office receives immediately before the making of the forecast, which takes place at 1.30 p. m., a short telegram from twelve selected stations in Austria-Hungary, giving the latest information as to changes in temperature, pressure, and cloudiness that have occurred at these stations since the morning observation. From this last item we can perceive with more certainty whether we have formed a correct idea as to the distribution of atmospheric pressure for the next day or not, and therefore whether to retain or modify the forecast. It is only after the data of the midday telegrams have been made use of that the definitive forecast is made. At 1.45 p. m. the weather report goes to the printer, and the corresponding telegrams are sent to those who have subscribed for the daily telegraphic forecasts.

The results of this system of honest weather forecasts are indeed modest, but are such as to show a real and striking progress in weather predictions as compared with other methods. Of course even this earnest scientific method allows us only to consider the general characteristics of the weather, as, for example, "fine," "windy," "mild," "fine and cold," "cloudy," "rainy," "warm," etc., as the object of the weather forecast. This method would immediately supplant all others if it would undertake to foretell the duration and amount of precipitation, the degree of the thermometer, the exact force of the wind, etc. However, we may at present be very well satisfied if the general character of the weather is predicted for us. Unfortunately even the scientific method can give us no positive certainty, since even by confining itself to these general characteristics it can at present offer only a little above 80 per cent of verifications of the weather.

In this state of the case it is self-evident that our efforts are to be guided in the direction of those studies that will lead us to an ever increasing accuracy in forecasting. These studies of course relate (1) to more and more thorough investigations of the weather conditions at every point and in every phase of the distribution of atmospheric pressure; (2) to the discovery of signs by which to form a judgment (*a*) as to the rapidity and paths with which each type of pressure distribution moves over Europe, (*b*) into what other forms a given type of distribution transforms itself and the rapidity of such change, and (*c*) what changes in the weather attend the various modifications of one

and the same type of atmospheric pressure distribution. With the increase of our knowledge on these points the weather predictions will also become more and more accurate. However, it is very doubtful whether it will ever be possible for us to invariably attain absolute accuracy even for one day in advance. Every increase in the percentage of verifications is, however, of the greatest value, especially to national economics.

Now, as a matter of course, the meteorologists are looking everywhere in order to take advantage of everything which may be of assistance to them in this matter. In the first place, there are the many good weather rules that have been deduced from the experience of many hundreds of years. But the greatest number and most valuable of these weather rules are only applicable to local weather predictions, whereas the central meteorological institutes must make their predictions for very distant countries also, as, for example, Austria for Dalmatia, Vorarlberg, Bukowina, etc.

Those weather rules, however, which relate to the weather conditions of certain definite dates, and which are generally looked upon as farmers' rules, are sometimes of great assistance in making forecasts. Thus we know that on certain dates of the year there has for centuries been a tendency to a certain kind of weather; for example, to rainy weather. Therefore, if at such periods the distribution of atmospheric pressure is of such a form that it may easily change to a type corresponding to the weather indicated by the farmers' rules, then we may be tolerably certain that we must forecast wet weather. But, on the other hand, if at some such period the distribution of pressure is of such a character as would ordinarily justify us in hoping for a change of weather, still we know that this change is not likely to occur, because there is a continued tendency at this period to wet weather, and a change of weather is not to be looked for. Such aid as this from farmers' rules is, however, of moderate value and rarely available. But it is quite otherwise, in the opinion of the believers in the moon, when we consider the support that the weather predictions might derive from hypotheses that attribute to the moon and the rest of the heavenly bodies a decided influence on the weather. I will express myself more in detail on this subject.

First and foremost, I must insist most strongly on the fact that professional meteorologists themselves have always recognized and do recognize one influence of one heavenly body as most decisive and the sole cause of the weather on our earth, viz, the heating of the earth and of its atmosphere by the sun. The sun regulates our weather; it gives rise to winter and summer; by evaporation it raises the aqueous vapor into the air, and this vapor, by cooling, produces clouds and rain, snow, storms, and hail; it is the primary cause of the differences in atmospheric pressure, and in this way produces the winds.

This heating influence of the sun, as also its modifications by cloudiness, by the wind, by the change from day to night or from winter to summer, and by the properties of the earth's surface, which, consisting as it does of water and of land either covered with vegetation or barren and bald, has varying capacities for absorbing the sun's heat—this influence of the heat of the sun has been established with the most absolute certainty by the most exact observations. It has been demonstrated to be so much more important than any other cause, if any such exists, that up to the present time it has not been possible to recognize any other cause with certainty, in spite of the fact that the professional meteorologists, and singularly enough they only, have instituted extensive and most thoroughly exact investigations in order to discover such other influences, in case there are any, and to determine their value. And what has been the result of these extraordinarily laborious and wearisome investigations? Before I answer this question I must call your attention to the fact that not one of the representatives of the theory of the influence of the moon, or of any other cosmical influence, has undertaken to give an unobjectionable rigorous demonstration of such an influence. These gentlemen content themselves with the inventive method and apply it in a very singular manner. They make their predictions for certain days and always call attention to the cases when they are successful, but never trouble themselves about the failures. Now, I beg you to observe that in every game of chance where there are but two alternatives there must occur fifty verifications out of every one hundred guesses, when a great number of guesses are made and it is all pure chance. The time at which the game of chance is played, or the time when the guess is made, is absolutely without any influence whatever upon the result. So, also, the drawing out of an even or uneven number of balls could have no influence upon the weather, even if it should occur to some one always to predict fine weather when he drew an even number and bad weather when he drew an uneven one. If, therefore, one should make use of the above-mentioned inventive methods, he should carefully record all the cases—the failures as well as the verifications. And then, even if every second case is a success—that is to say, even if he obtains 50 per cent of verifications—he will know that the theorem or assumption made use of as the basis of the predictions really has no causal connection with the weather. Only when more than 50 per cent of verifications are attained can the argument favor the assumption, and so much the more in proportion as the verifications exceed 50 per cent.

This exact method, the only one for testing their hypotheses as to the cosmical influences on the weather, is the one that has never been applied; in fact, it has often been distinctly rejected by those who maintain the existence of these influences; and yet those who make

assertions should prove them. It was the professional meteorologists themselves who undertook the accurate examination of all the various cosmical hypotheses, and particularly that of the influence of the moon, and it was they who found a slight influence of the moon on storms, thunderstorms, the direction of the wind, atmospheric pressure, etc. Now, do you say, "I told you so?" Well, first of all, observe—and I can not insist upon it too strongly—that it is the professional meteorologists, and they alone, who have made these investigations which point to a slight influence of the moon. Next, I must direct your attention to that little word "slight." The influence thus discovered by them is indeed so small that we can not even state with certainty whether it really does exist at all; or whether, perhaps, it was only perceptible in these investigations because the period of time included in them is still too short to furnish us with an unexceptionable result. However, let us assume that this slight influence really does exist, and let us examine the amount of this influence a little more closely. Its magnitude is expressed by the percentages of the favorable cases. We will, however, for once greatly exaggerate and assume that these favorable cases amount to a surplus of 5 per cent. That is to say, that in 100 cases 55 succeed and 45 fail. Now, if you use such lunar rules for weather predictions, what does it advantage you in isolated single cases? For instance, you are in doubt as to whether the rain is to be expected or not; the influence of the moon indicates rain with a weight of 0.05. In spite of this small weight, if now you forecast bad weather, you will, if 100 such cases occur, have a failure in 45 cases. Had you paid no attention to the influence of the moon you would possibly have had 50 failures. Thus, in this case of 5 per cent of surplus, that would be the whole effect of your consideration of the moon's influence. But we have in fact assumed an exaggerated case, and the real influence of the moon is in every case less than one-half of this, if indeed it really exists at all.

You may rest assured that the professional meteorologists accept, nay, even seek for, everything that can give them any assistance whatever in their weather predictions. By constant investigation and study we may hope to advance step by step and per cent by per cent. Every single per cent of agreement that is gained is an important advance and success.

PROGRESS WITH AIR SHIPS.[a]

By Maj. B. Baden-Powell, *Scots Guards.*

The advent of a really practical machine for accomplishing the navigation of the air is awaited with much interest, and the somewhat meager and unreliable information that one can pick up from the daily press is apt only to increase our anxiety to know what is really being done in this line. In the Illustrated Scientific News of June, I gave a brief sketch of the history of mechanically propelled balloons and what had been accomplished up to recent years. During this summer some distinct progress has been achieved in this line.

SANTOS DUMONT NO. 9.

M. Santos Dumont has, of course, been well to the fore, and though he has only been using his little No. 9 balloon, which may be likened to a motor bicycle as compared to a large motor car, yet he has been able to steer this apparatus and drive it about so easily that the accounts of his trips read as if practical aerial navigation had been achieved. But, so far as his particular performances go, we are still some way from this. It has only been during the calmest of weather that he has dared to venture forth, for his little 3-horsepower engine is incapable of propelling the vessel at any great speed. This machine is of a pointed ovoid shape, the length being 49 feet and the greatest diameter 18 feet. This compact form gives better stability than the more usual cigar shape, if it detracts from speed. The volume of the main gas vessel is 9,200 cubic feet; but this does not imply that so much gas is available for levitation, for of this 1,566 cubic feet is occupied by the "ballonet," which is kept partially full of air by a ventilating fan, so as to keep the whole balloon tightly distended. Along each side of the balloon a strip of canvas is sewn, in which is inclosed a number of short battens of wood, and from slings attached to these some 46 steel wires depend to support the frame. The latter, which is 29 feet long, is composed of pine rods of triangular section, braced with steel wires and kept apart by wooden triangles of varying size. Toward the front of this frame is the little basket car in which the aeronaut stands, and to the after side of this is fixed the motor. This

[a] Reprinted, after revision by the author, from the Illustrated Scientific News, London, Vol. I, No. 12, September, 1903.

is a Clement double-cylinder, air-cooled, petrol engine, weighing but 26.4 pounds and developing 3 horsepower, or less than 9 pounds per horsepower. The fly wheel is formed of a bicycle wheel, which weighs under 2 pounds and makes 1,600 revolutions. The steel shaft runs back from the motor to the propeller in rear. This is two-bladed, formed of steel tubes, covered with tightly stretched oiled silk. The propeller is 10 feet in diameter and 15 inches in greatest width. It weighs 24 pounds and makes 200 revolutions per minute, giving a thrust of 50 to 60 pounds. The balloon itself weighs only 30 pounds, and the whole apparatus, with framework, car, motor, etc., is under 200 pounds. A tapering trail rope, 100 feet long, hangs from the front of the balloon and is supported by a pulley under the rear end of the frame, so that the balance can be regulated. A large rudder, of 85 square feet, is placed under the after end of the balloon.

SANTOS DUMONT NO. 10.

The large Santos Dumont No. 10, the "Omnibus," of which a good deal has been heard, has not yet left its shed. Though it has been practically ready for some weeks, there seems to be some doubt as to how it may behave, and with so large a machine it does not do to run any risks. This new machine is far bigger than any of this aeronaut's former balloons, being nearly 200 feet long, and having a capacity of about 70,000 cubic feet. It is supposed to take 14 passengers, who are carried in three baskets hung below the long frame. The vessel is to be propelled by two screws, one at each end of the frame, and these are driven by a motor of 60 horsepower. A number of horizontal aeroplanes are arranged between the frame and the balloon, to aid in raising and lowering the apparatus.

SPENCER'S BALLOON.

In England we have also had an experiment with an air ship. Mr. Stanley Spencer constructed a new balloon, 93 feet long and 24 feet maximum diameter, containing 30,000 cubic feet. Below this was suspended a framework, similar to that used in the Santos Dumont balloons, 50 feet in length and stayed 4 feet apart by triangles of bamboo. The engine was a Simms motor of 24 horsepower. A screw propeller, 12 feet in diameter, was placed in front and a large rudder behind. On its first trial, however, the machine did not prove a success, failing to lift. We may look forward to a better result in future experiments.

DEUTSCH'S BALLOON.

Another large machine which is practically ready, and has been for some time, but which also seems to hesitate about starting on its maiden voyage, is the "Ville de Paris," belonging to M. Deutsch and designed by M. Tatin. The general design of this vessel is very much

THE LEBAUDY AIRSHIP.

THE CAR OF THE LEBAUDY AIRSHIP.

the same as that of M. Santos Dumont, but it has one or two peculiarities worth noting. Instead of the ordinary net, the balloon is covered with a "chemise" of unvarnished silk, to the lower edges of which a continuous boarding is attached. A square rudder is placed in rear, suspended from the end of a triangular framework. The screw, of the same form as the Santos Dumont, is 22 feet in diameter.

LEBAUDY'S BALLOON.

But of greater interest still is the air ship of Messrs. Lebaudy, which is kept ready inflated in its shed at Moisson. This is probably the most successful aerial machine ever made. It has now accomplished 29 voyages, in all of which, with one exception, it has successfully returned to its point of departure. As comparatively few details have been hitherto published about this machine, it may be interesting to give some. The gas vessel is long and finely pointed at the ends, and contains 80,000 cubic feet. It is composed of two thicknesses of cloth with a layer of india rubber in between, and the whole is painted bright yellow. The arrangement, designed by M. Julliot, is quite different to that adopted by so many other inventors. There is no long framework suspended below the balloon, but the lower surface of the latter is made flat, and a frame of steel tubing surrounds this plane. From the front part of this six steel tubes run diagonally down to the car, so as to convey the thrust of the propellers to the balloon, the car being supported by a number of steel-wire ropes. Below the plane is arranged a keel, consisting of a framework of steel tubing, covered along the after half of it with canvas. This keel is continued far away to the rear, where it ends with the rudder. Under the flat part of the balloon is a layer of uninflamable material, and all the portion above it is occupied by the air-filled ballonet, so that there is very little danger of the gas becoming ignited from the engines. The two safety valves to ease the pressure of the gas are also placed well out of reach behind.

The car consists of a boat-shaped frame of steel, partially covered in at the sides with canvas, the after part being left open, so as not to offer any resistance to the air. The engine, a Mercedes, of 40 horsepower, is placed in the center, the shaft running horizontally across and geared at right angles to the two propellers. The latter are 2.44 m. in diameter, and each consists of a steel bar, to which is fixed a thin plate of steel of a width equal to one-sixteenth of the circumference. These comparatively small propellers rotate at a considerable speed—about 1,000 turns per minute.

In the front part of the car, where the aeronaut in charge stands, may be seen the steering wheel, similar to that of a motor car. This is connected by means of an endless chain and wires to the rudder. Above this are the pressure gauges to show the compression of the

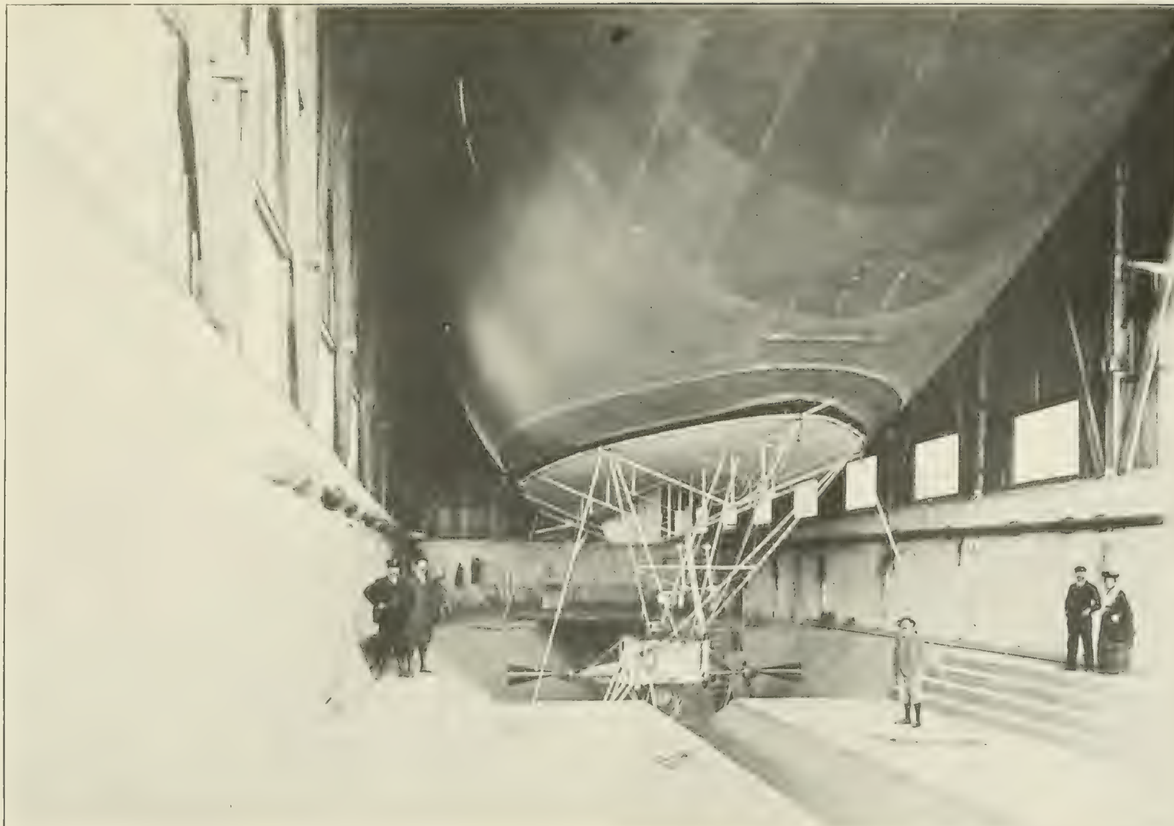
gas and of the air in the ballonet. To the aeronaut's left (in the photograph he is turned about) is the ventilator fan, driven by a belt from the engine, which drives air through the pipe up into this ballonet. To his right is a metal funnel, continued below the car, in which to empty the sand ballast, so as not to allow any dust to get into the engine. The engineer sits in rear of the motor, and here is to be seen another of the precautionary measures which are so abundantly provided. The white square seen in the photograph in rear of the engines is a thin plate of metal to protect the engineer in case of anything going wrong with the screw, a detached portion of which, traveling at so great a speed, might do much damage. Below the back of the car is the exhaust from the engine, the opening of which is inclosed in a ball of wire gauze. A store of oil to last fifteen hours is carried under the car. A small extincteur is carried in case of fire.

It is with some surprise that one notices how very strongly and solidly all these parts are constructed. Aluminum is conspicuous by its absence, everything is made of steel, and there seems no attempt to make it specially light.

The entire weight lifted by the balloon, including passengers, is given as 5,700 pounds.

The shed in which this enormous vessel is housed is also very well constructed. It is of wood, well stayed and trussed, with huge doors across one end. The floor is cemented, a well being made in the center for the car to rest in. The arrangements for guiding the airship out of the shed are very neat. Along each side of the hall, and along the center, run double rails close together. Four guy ropes depend from the balloon, two on each side. These end with an iron ring and ball, which ball is gripped by the rails, a similar ball is attached to the bottom of the car and is held by the third pair of rails. When the vessel is to be taken out, a man stands to each of the rings and slides it along the rails. The rails are continued outside the building, so that even when the machine is well outside, it is still secured by the guys. When all is ready to start, the ropes are detached from the rings and the balloon is free.

As regards the journeys actually made, the first proper ascent was effected on April 11, when the machine rose at 8.15 a. m. and remained up for half an hour, covering in that time 19 kilometers. Later in the same day it made a second ascent, and stayed up for an hour. On May 8 an important journey was made, the air ship proceeding to the town of Mantes, 10 kilometers distant, where it went through various evolutions, went on to Rosny, and then returned to its shed at Moisson, completing altogether some 23 miles in an hour and a half. On a later occasion even this record was beaten, the machine going a journey lasting two and three-quarter hours, and traversing over 61 miles. These trips were not, apparently, made during the most favorable



THE LEBAUDY AIRSHIP INSIDE THE SHED.

FIG. 1.—THE LEBAUDY AIRSHIP—VIEW FROM BELOW.

FIG. 2.—THE LEBAUDY SHED.

weather, for on the journey to Mantes it was said that rain, accompanied by a considerable wind, prevailed.

The greatest speed recorded is 11.80 meters per second (or over 25 miles per hour). Ascents have been made at all times of day, from 4 o'clock in the morning to 8 o'clock at night, even in fog and in frost. The balloon has recently remained for one hundred and ninety-six days inflated. The ascents were all conducted by the aeronaut, M. Juchmes.

BARTON'S BALLOON.

Another large air ship, though it has not at the time of writing yet made an ascent, should be nearly ready for its initial trials. This machine is very different in design to those I have just described. The shape of the gas vessel is to be somewhat like that of a shell, that is to say, cylindrical, with an ogival head and a blunt stern. Schwarz's balloon was roughly of this shape. It is composed of well-varnished silk, and will have a "chemise" of similar fabric unvarnished to go over the top instead of a net. Portions of the envelope, especially at the head, are stiffened with bamboo ribs. The balloon is about 170 feet long and some 50 feet in diameter. Underneath this is suspended a huge framework of stout bamboos, lashed together and trussed with wire stays. This is 140 feet long, and supports a deck which can be walked along from end to end. There are three separate engines, each of 50 horsepower. There are to be three pairs of propellers, each having several superposed blades. One of the main features of the apparatus is a series of aeroplanes, which are to assist the horizontal stability and the raising and lowering of the machine. The whole air ship is very big and cumbersome, but it has very powerful engines. If anything should go wrong with the latter, however, it will be a difficult balloon to manage.

OTHER AIR SHIPS.

An enormous machine is being constructed in San Francisco for Mr. Stanley. It is to be made almost entirely of aluminum. The shape is cylindrical, with conical ends, and it is 228 feet long. Propellers are to be fixed at each end as well as on the top, the latter being to regulate the rise and fall. It is supposed to take "at least 30 passengers." Another machine, but of more ordinary dimensions, is nearing completion in London. Mr. Beedle, the inventor, proposes to place a propeller at each end of the frame, but the front one is to be so arranged that its axis can be turned to one side to guide the vessel. It contains 24,000 cubic feet, and has engines of 16 horsepower.

AERIAL NAVIGATION.[a]

By O. Chanute, *Chicago, Ill.*

There are now dawnings of two possible solutions of the problem of aerial navigation, a problem which has impassioned men for perhaps four thousand or five thousand years. Navigable balloons have recently been developed to what is believed to be nearly the limit of their efficiency, and after three intelligent but unfortunate attempts by others a successful dynamic flying machine seems to have been produced by the Messrs. Wright.

It is therefore interesting to review the present status of the question, the prospects of its solution, and the probable uses of the hoped-for air ships.

BALLOONS.

As to balloons, we may pass over the early gropings and failures to make them navigable. It was recognized very soon that the spherical balloon was the sport of the wind; that it was necessary to elongate it in order to evade the resistance of the air, and that, inasmuch as aerial currents are much more rapid than aqueous currents, it was necessary to obtain considerable speeds in order to have a useful air ship. This means that there must be great driving power and that this power shall weigh as little as possible, for in any case the balloon itself, with its adjuncts and passengers, will absorb the greater part of its lifting power.

Giffard was the first to apply, in 1852, an artificial motor to an elongated balloon. This motor consisted in a steam engine of 3 horsepower, which weighed with its appurtenances 462 pounds, and Giffard obtained only 6.71 miles per hour, although his balloon was 144 feet long and 39 feet in diameter, or about the size of a tramp steamer.

Dupuy de Lome in 1872 went up with a balloon 118 feet long and 49 feet in diameter, but, having a wholesome dread of the contiguity of fire and inflammable gas, he employed man power (weighing about 2,000 pounds to the horsepower) to drive his screws, and he obtained

[a] Paper read before Section D, American Association for the Advancement of Science, December 30, 1903. Published by permission of the author.

less speed than Giffard. The accidents to Wölfert and to De Bradsky have since shown the soundness of his fears.

Next came Tissandier, in 1884, who employed an electric motor of 1½ horsepower, weighing some 616 pounds, with which he attained 7.82 miles per hour.

Meanwhile the French war department took up the problem. It availed itself of the labors of the previous experimenters and made careful and costly investigations of the best modes of construction, of the best shapes to cleave the air, and of the weight and efficiency of motors. This culminated in 1885, when Messrs. Renard and Krebs, of the aeronautical section, brought out the war balloon "La France," which attained about 14 miles an hour (or half the speed of a trotting horse) and returned to its shed five times out of the seven occasions on which it was publicly taken out.

This air ship was 165 feet long, 27½ feet in diameter, and was provided with an electric motor of 9 horsepower, weighing with its appurtenances some 1,174 pounds. The longitudinal section was parabolic, somewhat like a cigar rolled to a sharp point at both ends, the largest cross section being one-fourth of the distance from the front, and it was driven, blunt end foremost, by a screw attached at the front of the car. No better shape and arrangement have yet been devised, and subsequent experimenters who have wandered away therefrom have achieved inferior results, so far as the coefficient of resistance is concerned.

In 1893 the French war department built the "General Meusnier," named after an aeronautical officer of extraordinary merit of the first French Republic. This war balloon is said to be 230 feet long, 30 feet in diameter, 120,000 cubic feet in capacity, and to have been originally provided with a gasoline motor of 45 horsepower. It is said by all the writers on the subject that it was never taken out. Possibly the French were waiting for a war which fortunately never came; but, be this as it may, it is probable that with the reduction which has since taken place in gasoline motors this balloon could carry an engine of some 70 horsepower, and attain a speed of about 30 miles an hour, which is greater than that of trans-Atlantic steamers.

Some unsuccessful experiments were carried on in Germany in 1897, first by Doctor Wölfert, whose balloon was set on fire by his gasoline motor and exploded in the air, killing both himself and his engineer, and later by Schwarz, whose aluminum balloon proved unmanageable and was smashed in landing. The most ambitious attempt, however, was that of Count Zeppelin, who built in 1900, a monster air-ship 420 feet long and 39 feet in diameter. It was a cylinder with paraboloid ends, but the shape was inferior and almost all the lifting power was frittered away on an internal frame of aluminum, so that the gasoline motor could be of only 32 horsepower, and

the speed attained has variously been stated at 8 to 18 miles per hour. Nevertheless the design of Count Zeppelin contained many excellent features, and a movement is now on foot in Germany to enable him to try again, through means of a popular subscription. The mere size, if he builds again as large, is a great element of success, for as the cubic contents and lift increase as the cube of the dimensions, while the weights increase in a far smaller ratio, a balloon of this great size ought to be able to lift a very powerful motor, and to attain a speed of 30 or more miles per hour. He has shown that the size is not beyond the possibility of control.

Meanwhile gasoline motors had been increasing in efficiency and diminishing in weight. The French war department gave no sign and it was reserved for a Brazilian, Mr. Santos Dumont, to show to the Parisians what could be accomplished by equipping an air ship with a gasoline motor. The history of his triumphs is so present to all minds that it need only be alluded to, but it may be interesting to give some details of the sizes and arrangments of his various balloons. His first idea seems to have been that, in order to make it manageable, a balloon should be made as small as possible, and that it was practicable to disencumber it of many adjuncts hitherto considered indispensable. Neglecting to study carefully what had been found out by his predecessors, he had to learn by experience, and he built five balloons, all navigables, before he produced, in 1901, his No. 6, with which he won the Deutsch prize by sailing 3½ miles and return in half an hour. This balloon was 108 feet long, 20 feet in diameter, and was provided with a gasoline motor of 16 horsepower which might be driven up to 18 or 20 horsepower. While the speed over the ground was 14 miles an hour, retarded as it was by a light wind, the speed through the air was about 19 miles an hour, a small but marked advance over any previous performance; but the result would have been still better if the shape had been that of Colonel Renard's balloon.

Since then Mr. Santos Dumont has built four new navigable balloons: His No. 7, with which he expects to compete at St. Louis in 1904, is 160 feet long and 23 feet in diameter, and is to be provided with a motor of 60 horsepower; his No. 8, which was sold to parties in New York last year; his No. 9, which is his visiting balloon, being only 50 feet long and 18 feet in diameter and provided with a 3-horsepower motor. Its speed is only 10 miles an hour, but it is handy to ride around to breakfast or afternoon teas. He is now finishing his No. 10, the omnibus, which is 157 feet long and 28 feet in diameter, with a motor of 46 horsepower. Fares are to be charged for by the pound of passenger when it comes out next spring.

Emulators of Santos Dumont there have been that have come to grief. Mr. Roze built in 1901 a catamaran consisting of two twin balloons, which, although 148 feet long, failed to raise their own

weight serviceably. Mr. Severo built in 1902 a navigable balloon which was so injudiciously constructed that the car broke away in the air, and the inventor was killed as well as his engineer. Later in the same year De Bradsky built a navigable balloon equipped with a gasoline motor located so near the vent for the gas that the latter took fire, exploded the balloon, and the inventor and his engineer were killed, thus for the second time verifying the fears of the experts who discountenanced this combination.

Some meritorious projects have been published, but not yet carried out. Among these may be mentioned that of Mr. Yon, now deceased, and that of Mr. Louis Godard. The latter project was for a balloon 180 feet long and 36 feet in diameter, with two steam motors of 50 horsepower each. It was expected to attain a speed of 30 miles per hour.

One navigable balloon which was built this year, that of the Lebaudy brothers, has achieved a great success. It is 185 feet long, 32 feet in diameter, and is equipped with a gasoline motor of 40 horsepower. It has beaten the speed of Santos Dumont, having on many occasions, it is said, attained 24 miles an hour.

There is also a navigable balloon being built in Paris by Mr. Tatin for Mr. Deutsch, the donor of the famous prize. This is 183 feet long, 27 feet in diameter, and is equipped with a gasoline motor of 60 horsepower.

Besides these there are said to be a number of navigable balloons either being built or proposed in France. They are those of the Marquis de Dion, of Pillet & Robert, of Girardot, of Boisset, and of Bourgoin, but there is no telling how many of them will materialize.

These are all French balloons, while there are in England the balloon of Mr. Spencer, 93 feet by 24 feet, with nominally 24 horsepower; of Mr. Beedle, 93 feet by 24 feet, with 12 horsepower, and that of Doctor Barton, now in construction, with dimensions of 170 feet in length, 40 feet in diameter, and equipped with a number of aeroplanes and three gasoline motors of 50 horsepower each. It is a question whether the weight of the aeroplanes will leave sufficient margin to lift 150 horsepower.

The ultimate practicable size for balloons is not yet known, but the mathematics of the subject are now tolerably well understood. The larger the balloon the more speed it can attain, and it is possible to design it so that the results shall not be disappointing. Those inventors who expect to attain 70 to 100 miles an hour by some happy combination do not know what they are talking about.

It is interesting to speculate which of the above-mentioned navigable balloons would, if competing, stand a chance of winning the $100,000 prize which has been offered by the St. Louis exposition of 1904. So far as can now be discerned, the only vessels which are

likely to develop the required minimum speed of 20 miles an hour over the ground, which speed really requires about 25 miles an hour through the air, as there will almost invariably be some wind, will be the Santos Dumont No. 7, the Lebaudy and the Deutsch air ships, all of them French. The English vessels of Spencer and of Beedle are too small to lift sufficient power to drive them at 25 miles an hour. The balloon of Doctor Barton might gain this speed if it were not 40 feet in diameter, besides being loaded down with aeroplanes, and it remains to be seen what will be the effect of this combination. The American air ships all seem to be too small to lift enough power to give them the required speed save the Stanley air ship, 228 feet by 56 feet in diameter, begun in San Francisco. Should this be completed in time, and should the weights be kept approximately near those stated in the circulars, it might have a chance to obtain 25 miles an hour, but it would need more than three times the 50 horsepower contemplated in order to do so, and the weight of the aluminum shell and framing would probably absorb much of the lifting power.

FLYING MACHINES.

If the aeronautical contest at St. Louis were scheduled to take place a few years later, thus giving time to consummate recent success, it is not improbable that the main prize would be carried off by a flying machine. This yet lacks the safe flotation in the air which appertains to balloons, but it promises to be eventually very much faster.

The writer found, somewhat to his surprise, when on a visit to Paris last April, that a decided reaction had set in among the French against balloons. It seemed to be realized that the limit of speed had been nearly reached for the present, and that but small utility was to be expected from navigable balloons. They must be large, costly, and require expensive housing, while they are slow and frail and carry very small loads. As commercial carriers they are not to be thought of, but they may be useful in war and in exploration.

Hence the French are turning their thoughts toward aviation and propose to repeat some of the experiments with gliding machines which have taken place in America. Even Colonel Renard, the celebrated pioneer of the modern navigable balloon, is now said to have become a convert to aviation and to say that the time has come to try the system of combined aeroplanes and lifting screws for flying apparatus.

A good deal of experimenting has been done with power-driven flying models. The more recent types have been actuated by twisted rubber threads, by compressed air and by steam, and the most notable experiments in order of date are those of Penaud, Tatin, Hargrave, Phillips, Langley and Tatin, and Richet. The data of these (except the first) will be found by searchers in such matters in the London

Times edition of the Encyclopædia Britannica, in the article on aeronautics. The most successful experiment was that of Professor Langley, who obtained in 1896 three flights of about three-fourths of a mile each with steam-driven models, the apparatus alighting safely each time and being in condition to be flown again.

The one great fact which appears from all these various model experiments is that it requires a relatively enormous power to obtain support on the air. Omitting the cases in which the power was probably overestimated, the weights sustained were but 30 to 55 pounds to the horsepower expended, thus comparing most unfavorably with the weights transported by land or by water; for a locomotive can haul about 4,000 pounds to the horsepower upon a level track, and a steamer can propel a displacement of 4,000 pounds per horsepower on the water at a speed of 14 miles an hour.

But models are, to a certain extent, misleading. They seldom fly twice alike and they do not unfold the vicissitudes of their flight. Moreover, the design for a small model is sometimes quite unsuited for a large machine, just as the design for a bridge of 10 feet opening is unsuited for a span of one hundred feet.

After experimenting with models three celebrated inventors have passed on to full-sized machines to carry a man. They are Maxim, Ader, and Langley, and all three have been unsuccessful, simply because their apparatus did not possess the required stability. They might have flown had the required equilibrium and strength been duly provided.

At a cost of about $100,000, Sir Hiram Maxim built and tested in 1894 an enormous flying machine, to carry three men. It consisted in a combination of superposed aeroplanes, portions of which bagged under air pressure, and it was driven by two screws 17 feet 10 inches in diameter, actuated by a steam engine of 363 horsepower with steam at 275 pounds pressure. The supporting surface was about 4,000 square feet, and the weight 8,000 pounds. The machine ran on a track of 8-feet gauge, and was prevented from unduly rising by a track above it of 30-feet gauge. At a speed of 36 miles per hour all the weight was sustained by the air, and on the last test the lifting effect became so great that the rear axle trees were doubled up, and finally one of the front wheels tore up about 100 feet of the upper track, when steam was shut off and the machine dropped to the ground and was broken. Its short flight disclosed that its stability was imperfect and Sir Hiram Maxim has not yet undertaken the construction of the improved machine which he is understood to have had under contemplation.

Having already built, in 1872 and 1891, two full-sized flying machines with doubtful results, Mr. Ader, a French electrical inventor, built, in 1897, a third machine at a cost of about $100,000 furnished by the

French war department. It was like a great bird, with 270 feet supporting surface and 1,100 pounds weight, being driven by a pair of screws actuated by a steam engine of 40 horsepower, which weighed about 7 pounds per horsepower. Upon being tested under the supervision of the French army officers, the equilibrium was found so defective that further advance of funds was refused. The amount lifted per horsepower was 27 pounds.

The data for the full-sized flying machine of Professor Langley, tested October 7 and December 8, 1903, have not yet been published. From newspaper photographs it appears to be an amplification of the models which flew successfully in 1896, and this, necessarily, would make it very frail. The failures, however, seem to have been caused by the launching gear and do not prove that this machine is useless. Like the failures of Maxim and of Ader, it does indicate that a better design must be sought for, and that the first requisites are that the machine shall be stable in the air, shall be quite under the control of its operator, and that he, paradoxical as it may appear, shall have acquired thorough experience in managing it before he attempts to fly with it.

This was the kind of practical efficiency acquired by the Wright brothers, whose flying machine was successfully tested on the 17th of December. For three years they experimented with gliding machines, as will be described further on, and it was only after they had obtained thorough command of their movements in the air that they ventured to add a motor. How they accomplished this must be reserved for them to explain, as they are not yet ready to make known the construction of their machine nor its mode of operation. Too much praise can not be awarded to these gentlemen. Being accomplished mechanics, they designed and built the apparatus, applying thereto a new and effective mode of control of their own. They learned its use at considerable personal risk of accident. They planned and built the motor, having found none in the market deemed suitable. They evolved a novel and superior form of propeller; and all this was done with their own hands, without financial help from anybody.

Meantime it is interesting to trace the evolution which has led to this result and the successive steps which have been taken by others.

It is not enough to design and build an adequate flying machine; one must know how to use it. There is a bit of tuition which most of us have seen—that of the parent birds teaching their young to fly—which demonstrates this proposition. Even with thousands of years' evolution and heredity, with adequate flying organs, the birdlings need instruction and experience.

Safety is the all-important requisite. It is indispensable to have a flying machine which shall be stable in the air and to learn to master its management. Nothing but practice, practice, practice will gain

the latter, and upon this the school of Lilienthal and his followers is founded.

Otto Lilienthal was a German engineer of great originality and talent, who, after making very valuable researches, assisted by his brother, published a book in 1889, Der Vogelflug als Grundlage der Fliegekunst, which it is very desirable to have translated and published for the benefit of English investigators. Then, putting his theories to the test of practice, he built, from 1891 to 1896, a number of aeroplane machines with which he diligently trained himself in gliding flight, using gravity for a motive power, by starting from hillsides. He grew exceedingly expert, and made, it is said, more than 2,000 flights, until one rueful day (August 9, 1896) he was upset and killed by a wind gust, probably in consequence of having allowed his apparatus to get out of order.

He was followed by Mr. Pilcher, an English marine engineer, who slightly improved the apparatus, but who, after making many hundred glides, was also upset and killed in October, 1899, through structural weakness of his machine.

The basis for the equilibrium of an apparatus gliding upon the air being that the center of gravity shall be on the same vertical line as the center of air pressure, both Lilienthal and Pilcher reestablished this condition by moving their bodily weight to the same extent that the center of pressure varied through the turmoils of the wind. The writer ventured to think this method erroneous, and proposed to reverse it by causing the surfaces themselves to alter their position, so as to bring the center of pressure back vertically over the center of gravity. He began experimentally with man-carrying gliding machines in June, 1896, and has since built six machines of five different types, with three of which several thousand glides have been effected without any accidents. The first was a Lilienthal machine, in order to test the known before passing to the unknown, and this was discarded some six weeks before Lilienthal's sad accident.

With three of the other machines favorable results were obtained. The best were with the "two-surface" machine, equipped with an elastic rudder attachment designed by Mr. Herring, and this was described and figured in the Aeronautical Annual for 1897.

Three years later Messrs. Wilbur and Orville Wright took up the problem afresh and have worked independently. These gentlemen have placed the rudder in front, where it proves more effective than in the rear, and have placed the operator horizontally on the machine, thus diminishing by four-fifths the resistance of the man's body from that which obtained with their predecessors. In 1900, 1901, 1902, and 1903 they made thousands of glides without accidents, and even succeeded in hovering in the air for a minute and more at a time. They had obtained almost complete mastery over their apparatus before they

ventured to add the motor and propeller. This, in the judgment of the present writer, is the only course of training by which others may hope to accomplish success. It is a mistake to undertake too much at once and to design and build a full-sized flying machine ab initio, for the motor and propeller introduce complications which had best be avoided until in the vicissitudes of the winds bird craft has been learned with gravity as a motive power.

Now that an initial success has been achieved with a flying machine, we can discern some of the uses of such apparatus, and also some of its limitations. It doubtless will require some time and a good deal of experimenting, not devoid of danger, to develop the machine to practical utility. Its first application will probably be military. We can conceive how useful it might be in surveying a field of battle, or in patrolling mountains and jungles over which ordinary means of conveyance are difficult. In reaching otherwise inaccessible places, such as cliffs, in conveying messages, perhaps in carrying life lines to wrecked vessels, the flying machine may prove preferable to existing methods, and it may even carry mails in special cases, but the useful loads carried will be very small. The machines will eventually be fast, they will be used in sport, but they are not to be thought of as commercial carriers. To say nothing of the danger, the sizes must remain small and the passengers few, because the weight will, for the same design, increase as the cube of the dimensions, while the supporting surfaces will only increase as the square. It is true that when higher speeds become safe it will require fewer square feet of surface to carry a man, and that dimensions will actually decrease, but this will not be enough to carry much greater extraneous loads, such as a store of explosives or big guns to shoot them. The power required will always be great, say something like one horsepower to every hundred pounds of weight, and hence fuel can not be carried for long single journeys. The north pole and the interior of Sahara may preserve their secrets a while longer.

Upon the whole, navigable balloons and flying machines will constitute a great mechanical triumph for man, but they will not materially upset existing conditions as has sometimes been predicted. Their design and performance will doubtless be improved from time to time, and they will probably develop new uses of their own which have not yet been thought of.

GRAHAM BELL'S TETRAHEDRAL KITES.[a]

In the June number of the National Geographic Magazine (Washington, D. C.) is a very interesting and instructive article by Dr. Graham Bell on the tetrahedral principle in kite structure. The article itself is so concise and depends so much upon illustrations, which are reproduced to the number of 20 in the text and 70 in the Appendix, that an effective representation of the contents in an article of smaller dimensions is scarcely possible. Still the line of thought that runs through the work which the article represents is so clear and so suggestive that even an imperfect outline of it may be useful. Doctor Bell indicates certain stages in the development of his ideas as "milestones" of progress, and since the ultimate stage of the development is the possibility of building up very large kite structures by combining unit cells in such a way that the proportion of weight to wing area in the structure is nearly the same as that of the constituent cell the successive stages are noteworthy. They sketch out in a most interesting manner a reply to Newcomb's criticism of the limits of application of the aeroplane based upon the argument that increase of size means diminished efficiency because, for similar structures, the weight varies as the cube, while the area, upon which the lifting force depends, varies as the square of the linear dimensions.

The original stage, the ordinary kite, is a single plane structure. The first step in advance is the Hargrave box kite, with its upper and lower aeroplanes for its support and side planes for stability. To stiffen the framework of the box kite it must be braced longitudinally and transversely. Accordingly Graham Bell's development commences by replacing the rectangular framework of the box kite by a framework of triangular section, which is by construction stiff so far as the cross section is concerned. The inclined sides are by the vector principle of resolution of forces regarded as equivalent to their geometrical projections, and, in so far as the principle applies, the inclined

[a] Reprinted from Nature, London, August 13, 1903, No. 1763, vol. 68, pp. 347-349.

faces represent the combined effect of aeroplanes of the area of the projections.[a]

The box kite of triangular section is, however, not stiff as regards longitudinal shear, and the next "milestone" marks the reduction of the triangular or prismatic form to the tetrahedron, an essentially stiff framework for all directions. A tetrahedron of rods with two adjacent faces covered with fabric forms a tetrahedral kite cell which, on the principle of projection before referred to, is equivalent to three aeroplanes represented by the projections of the covered sides upon planes at right angles.

The further development of pure tetrahedral construction is obvious. Four cells can be combined to form a tetrahedron of double linear dimensions without additional framework; the weight and wing area are both simply proportional to the number of cells, and not to the linear dimensions. For each set of four cells thus combined there is an octahedral free space in the interior which corresponds to the free space between the two cells of the Hargrave kite. The tetrahedral kites that have the largest central spaces preserve their equilibrium best in the air.

Combining 4 multiple cells to fill the outline of a tetrahedron of double size, again, we get a 16-cell kite, and repeating the process again a 64-cell kite, occupying a tetrahedron eight times the dimensions of a single cell. The building up of multicellular kites from the units is represented in the figures here reproduced from illustrations in Doctor Bell's article. Fig. 1, Pl. I, represents the unit cell; fig. 2 a combination of 4 cells; fig. 3 of 64 cells.

The kites fly with the points of the wings upward; the line of junction of the covered faces of the tetrahedron forms a kind of keel. No details as to the heights attainable are given. The most convenient place for the attachment of the flying end is said to be the extreme point of the bow. If the cord is attached to points successively farther back on the keel, the flying end makes a greater and greater angle with the horizon, and the kite flies more nearly overhead; but it is not advisable to carry the point of attachment as far back as the middle of the keel. A good place for high flights is a point halfway between the bow and the middle of the keel.

"Tetrahedral kites combine in a marked degree the qualities of strength, lightness, and steady flight; but further experiments are required before deciding that this form is the best for a kite or that

[a] This principle to be generally applicable would require the normal component of wind pressure to be uniform and independent of the angle between the plane and the wind. This is not the case with an aeroplane (see Rayleigh, Nature, vol. xxv, p. 108); and for the principle to be applied approximately in the case of the kites some convention as regards the angle of exposure of the aeroplanes to the wind would be required.

FIG. 1.—A WINGED TETRAHEDRAL CELL.

FIG. 2.—A 4-CELLED TETRAHEDRAL KITE.

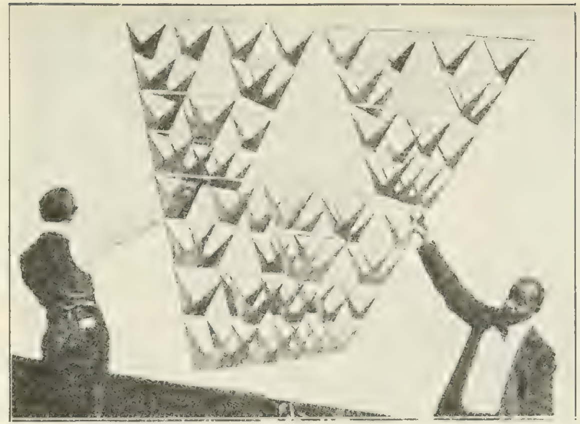


FIG. 3.—A 64-CELLED TETRAHEDRAL KITE.

FIG. 4.—THE AERODROME KITE.

winged cells without horizontal aeroplanes constitute the best arrangement of aero-surfaces.

"The tetrahedral principle enables us to construct out of light materials solid frameworks of almost any desired form, and the resulting structures are admirably adapted for the support of aero-surfaces of any desired kind, size, or shape."

The diagrams illustrating the article show various examples of the formation of complex kites from tetrahedral cells. One form suggested by Professor Langley's aerodrome, but different in construction and appearance, is shown in fig. 4, reproduced from an illustration in the article. That some of these complex kites are on a very large scale is evident from a case cited, in which an aerodrome kite, which was struck by a squall before it was let go, lifted two men off their feet, and subsequently broke its flying cord, a Manila rope of three-eighths inch diameter.

The simplicity of the construction of the cells, and the obvious possibilities of their combination, lend an additional fascination to a subject which is already full of interest.

RADIUM.[a]

By E. Curie,
Professeur à la Faculté des Sciences de l'Université de Paris.

M. Becquerel discovered in 1896 that uranium and its products emit spontaneously radiations which, like the Röntgen rays, are photographically active, augment the electrical conductivity of the air through which they pass, traverse black paper and thin sheets of metal freely, but can neither be reflected nor refracted.[b]

Compounds of thorium emit radiations analogous in their properties, and of comparable intensity.[c] The radiations thus spontaneously emitted by certain substances received the name "Becquerel rays," and we are accustomed to speak of the substances emitting them as radio-active.

Madame Curie and myself have discovered new radio-active substances existing in minute quantities in certain minerals, but possessing the property of radio-activity in a very high degree. We have separated the radio-active substance polonium, analogous to bismuth in its chemical reactions, and radium[d] which more resembles barium. M. Debierne has since separated actinium, which is a radio-active substance to be classed chemically with the rare earths.[e]

Polonium, radium, and actinium emit radiations of an order of intensity a million times higher than those emitted by uranium and thorium, and have enabled physicists to conduct many investigations of the phenomena of radio-activity within the past few years. The present paper is confined to the description of radium, which we have proved to be a new element, and have succeeded in isolating in the form of a pure salt.[f] This is the substance which has been most widely used in researches on radio-activity.

[a] Translated from a lecture delivered by Prof. E. Curie before the Royal Institution of London, as printed in the Revue Scientifique February 13, 1904.

[b] Becquerel, Comptes rendus de l'Academie des Sciences, 1896 and 1897. Rutherford, Phil. Mag., 1899.

[c] Schmidt, Wied. Ann., Band 65, p. 141. Madame Curie, Comptes rendus de l'Academie des Sciences, April, 1898.

[d] Discovered in an investigation shared with M. Bémont.

[e] P. Curie and Mme. Curie, C. R. de l'Academie des Sciences, July, 1898. P. Curie, Mme. Curie, and M. Bémont, C. R., December, 1898. Debierne, C. R., October, 1899, and April, 1900.

[f] Mme. Curie. Thèse à la Faculté des Sciences de Paris, 1903.

II.

The radiations of radium produce photographic impressions very quickly, and are able to penetrate any screen whatsoever. Bodies differ in transparency, but no screen is absolutely opaque to radium rays.

The radiations of radium excite phosphorescence in a great number of bodies, including, among others, the following: Alkaline salts, alkaline earths, organic substances, the skin, glass, paper, salts of uranium, etc., while diamond, platino-cyanide of barium, and the phosphorescent sulphide of zinc of Sidot are particularly sensitive. The luminescence of phosphorescent sulphide of zinc persists for some time after the removal of the radium which excites it.

Radium emits its rays with equal intensity whether immersed in liquid air at $-180°$ C. or at ordinary temperatures. When a bit of radium salt is placed with a little screen of platino-cyanide of barium in a test tube and the whole plunged into liquid air, the screen appears to glow at least as strongly as before. Under the same circumstances a screen of sulphide of zinc loses some of its luminosity, but this is owing to the diminished phosphorescent power of this substance at low temperatures.

Little by little phosphorescent substances are altered under the prolonged action of radium and become less readily excited and less luminous.

The salts of radium are spontaneously luminous, and it may be presumed that they render themselves phosphorescent by their own radioactivity. Radium-chloride and radium-bromide are the most intensely luminous of these salts, and may even appear visibly bright in open daylight. In these circumstances the light emitted by the radium recalls to mind the color of that given by the firefly or glowworm. The luminosity of radium salts diminishes with lapse of time, but never wholly disappears, and salts at first uncolored become at length tinged with gray, yellow, or violet.

III.

The radiations of radium impart electrical conductivity to the air through which they pass. When a fragment of radium salt is brought near a charged electroscope the latter is immediately discharged. If the electroscope is inclosed by a thick, solid wall the discharge still takes place, though more slowly. Lead and platinum are strongly absorbent, but aluminum is the most transparent of the metals, and organic substances absorb relatively little of the Becquerel rays.

Noncondneting liquids, such as petroleum ether, sulphide of carbon, benzine, and liquid air are rendered conducting under the influence of radium.[a]

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[a] P. Curie, C. R., February 17, 1902.

Under certain conditions the radiations of radium facilitate the passage of sparks between two conductors placed in air. This is illustrated by the apparatus shown in fig. 1, consisting of an induction coil, B, from the poles, P and P′, of which two metallic circuits are led to micrometric sparking devices, M and M′, at considerable distance apart, and offering two distinct paths of equal resistance to the passage of sparks. The micrometers are adjusted so that each transmits equally an abundance of sparks between their terminals. Upon bringing a fragment of radium near one of the micrometers the sparks cease to pass at the other.

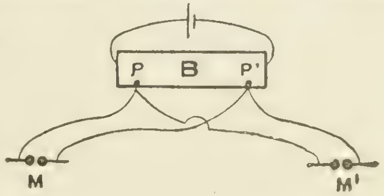

FIG. 1.—Conductivity of air augmented by radium.

It appears to be the most penetrating rays which are most effective in promoting electrical conductivity, for the efficiency of the rays for this purpose is not greatly reduced by interposing a lead screen 2 centimeters thick, although the larger portion of the rays is arrested by such a screen.

IV.

The radiations of radium can be neither reflected nor refracted. They form a heterogeneous mixture, separable into three groups, which following the nomenclature of Rutherford we will designate by the Greek letters α, β, and γ. These groups may be discriminated by the aid of the magnetic field; for in an intense magnetic field the α rays are slightly deviated from a rectilinear course in the same manner as the "canal rays" in vacuum tubes, while the β rays are deviated like the cathode rays, and the γ rays, like those of Röntgen, are not deviated at all.[a]

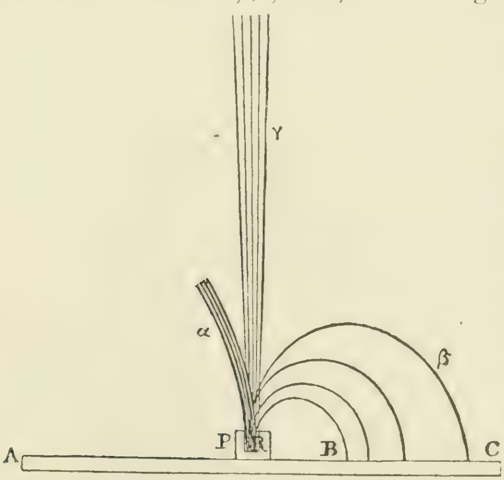

FIG. 2.—Magnetic separation of α, β, and γ rays.

A bit of radium (R, fig. 2) is placed within a small cavity in a block of lead. In the absence of all magnetic action the radiation escapes from the block as a rectilinear pencil, but in a uniform magnetic field normal to the plane of the figure,

[a] Giesel, Wied. Ann., November 2, 1899. Meyer and Von Schweidler, Akad. Anzeig. Wien, November 3 and 9, 1899. Becquerel, C. R., December 11, 1899, January 26 and February 16, 1903. P. Curie, C. R., January 8, 1900. Villard, C. R., Vol. CXXX, p. 1010. Rutherford, Physik-Zeitsch., January 15, 1903.

and directed toward the rear of this plane, the β rays are strongly deflected toward the right and caused to follow a circular trajectory; the α rays are slightly deviated toward the left, while the γ rays, which are far the least abundant, continue in a straight line.

The α rays are of slight penetrating power. A sheet of aluminum only a few hundredths of a millimeter in thickness absorbs them. To exhibit their deviation a very intense magnetic field is required, and the actual demonstration requires a far more delicate method than that indicated in fig. 2, which is merely a diagram given in general illustration.[a]

The α rays may be compared to projectiles of atomic dimensions charged with positive electricity and shot off with great velocities. Apart from their behavior in a magnetic field, the α rays may be recognized by their manner of absorption in a succession of thin screens.[b] In traversing successively a series of screens the α rays become less and less penetrating, whereas residual Röntgen rays under these circumstances become more and more penetrating. It appears that the energy of each projectile becomes less with each screen that it passes.

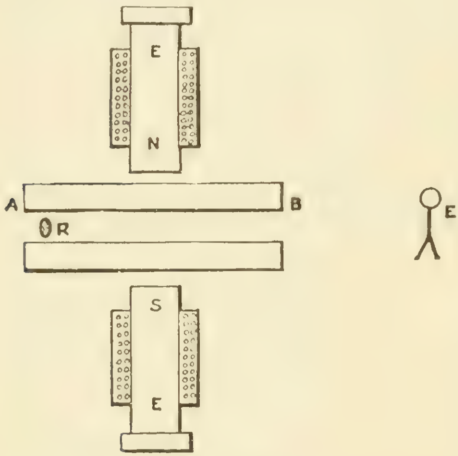

Fig. 3.—Magnetic deviation of β rays.

It is the α rays which appear to be active in the beautiful experiment exhibited by the spinthariscope of Sir William Crookes. In this apparatus a small fragment of radium salt (only a fraction of a milligram) is suspended by a metallic wire at a small distance (one-half millimeter) from a screen of phosphorescent sulphide of zinc. When the face of the screen which is turned toward the radium is examined in darkness by the aid of a magnifying glass, it appears studded with sparkling points, reminding one of the stars in the sky, except that these luminous points are appearing and disappearing continually. It may be supposed that each bright point which appears is the result of the impact of a projectile, and thus for the first time there has been discovered a means of distinguishing an individual action of an atom.

The β rays are analogous to the cathode rays and behave similarly in the magnetic field. They comport themselves as projectiles charged negatively and escaping from the radium with high velocity. These projectiles (electrons) appear to have a mass about one thousand times

[a] Rutherford, Phil. Mag., February, 1903. Becquerel, C. R., Vol. CXXXVI, p. 199.

[b] Mme. Curie, C. R., January 8, 1900.

smaller than the hydrogen atom. By means of the following experiment the magnetic deviation of the β rays may be demonstrated. A tiny phial holding a little radium, R, is placed at one end of a thick-walled lead tube, AB, as shown in section in fig. 3. An electroscope is placed somewhat beyond the other end of the tube, so that the pencil of rays emerging from the tube tends to discharge the electroscope. The lead tube is situated between the poles of an electro-magnet, E E, and at right angles to the line of poles, N S. When the current is flowing in the coils of the electro-magnet the β rays are thrown upon the walls of the lead tube, and do not escape to discharge the electro-

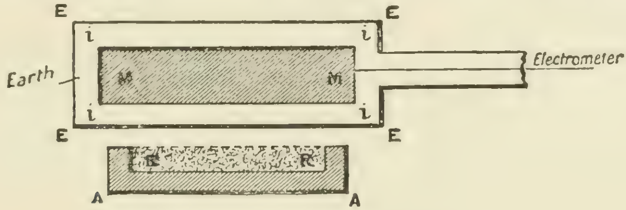

FIG. 4.—Negative electrical charges transported by β rays.

scope as before, so that it now discharges more slowly. When the current is cut off the electroscope is again rapidly discharged.

It may be shown that the β rays transport negative electricity, which is in harmony with the hypothesis that they are electrically charged projectiles.[a] For this experiment the apparatus illustrated in fig. 4 may be employed, in which R R represents the radium emitting the β rays. Those among them which are directed toward the upper part of the figure traverse successively a thin sheet of aluminum, E E E E, in electrical contact with the earth, and supporting an insulating block of paraffin, *i i i i*. They are finally absorbed by a lead block, M M, which is connected to an electrometer by an insulated wire. It is

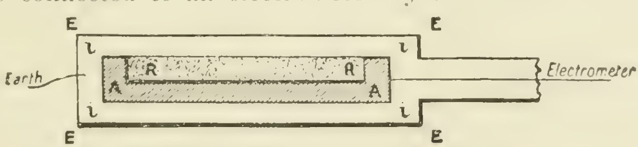

FIG. 5.—Negative charges carried by β rays.

found that the electrometer is continually charged negatively. In this experiment the α rays are absorbed by the sheet of aluminum which is connected to earth. The layer of paraffin is required to insulate the lead block M M, for the insulation of this block would be defective if there was only air between it and the aluminum, on account of the air being rendered conducting by the presence of the rays, so that it would then be impossible to detect at the electrometer the charging of the lead block.

An experiment the inverse of this may be performed. The metallic trough A A (fig. 5) containing radium, R, is connected with the elec-

[a] M. and Mme. Curie, C. R., March 5, 1900.

trometer and surrounded by paraffin, *i i i i*, inclosed in the metallic envelope E E E E, which is connected to earth. Since the α rays are but feebly penetrating they can not escape, but the β rays traverse the paraffin and carry off negative electricity, so that the trough A A becomes positively charged.

A sealed glass test tube containing radium salt becomes spontaneously charged with electricity, as if it were a Leyden jar. If, after a sufficient time, a line is traced by a glass cutter on the wall of the test tube, a spark may pass at the point where the wall is thinned by the scratch, and at the same time the operator receives a feeble shock in his fingers by the passage of the discharge.

The group of β rays is made up of a variety of rays differing in their penetrating power. Some β rays are absorbed by a thickness of one one-hundredth millimeter of aluminum, while others are able to traverse, before complete absorption, a layer of lead several millimeters in thickness. Another method of distinguishing the varieties of β rays is by the curvature of their path in a magnetic field. In the experiment represented in fig. 2 the β rays deviated by the magnetic field would darken a photographic plate all the way from B to C. The least deviated rays would be distinguished at C and those most deviated at B. Thus there would appear the photograph of a sort of spectrum produced by the influence of the magnetic field on the β rays. By interposing a thin sheet of metal in the path of the rays, it may be shown that the rays most deviated are suppressed, so that it appears that the most penetrating rays are least deviated.[a]

According to the ballistic theory, it may be assumed that the β rays are composed of electrons projected with different velocities. The most penetrating rays have the highest velocity. Kaufmann's researches, interpreted in the light of the theory of electrons as given by M. Abraham, lead to very important general conclusions. Certain very penetrating β rays may consist of electrons impressed with a velocity nine-tenths of that of light. The property of mass in electrons, and perhaps in all bodies, may be a consequence of electro-magnetic reactions. The energy required to impress higher and higher velocities upon an electrically charged body approaches infinity when the velocity of the body approaches the velocity of light.

The γ rays, which are not deviable in a magnetic field, and which are analogous to X-rays, form but a small part of the total radiation. Certain γ rays are extremely penetrating, and are able to traverse a thickness of several centimeters of lead.

Becquerel rays may be utilized to make radiographs without special apparatus. A small glass test tube containing some hundredths of a gram of radium salt replaces the Crookes tube. Both β and γ rays are employed, but such radiographs lack sharpness on account of the

[a] Becquerel, C. R., Vol. CXXX, pp. 206, 372, 810.

diffusion of the β rays by the bodies through which they pass. Sharp radiographs are obtained by deflecting the β rays with a magnetic field, so that only the γ rays remain; but the γ rays are so feeble that several days' exposure must then be employed.

V.

Radium salts continually give off heat.[a] The evolution of heat is so great that it may be shown in a rough experiment made with two ordinary mercury thermometers. Two similar vacuum-jacketed receptacles (A and A′, Fig. 6) are employed. In one of them, A, let us suppose, is placed a test tube containing 0.7 gram of pure radium bromide, and in the second, A′, is a similar tube of inactive substance such as chloride of barium. The temperature of each inclosure is indicated by a thermometer whose bulb is close to the test tube. The top of each vessel is closed by a wad of cotton. In these conditions the thermometer t, which is placed in the same vessel with the radium, continually indicates a temperature about 3° higher than that of the other thermometer t′.

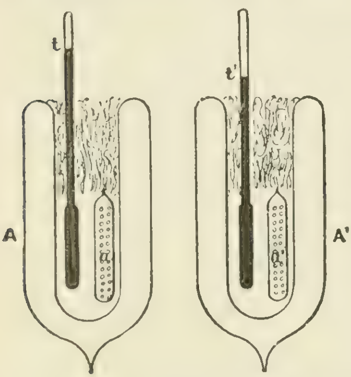

FIG. 6.—Continuous evolution of heat by radium.

A determination of the amount of heat emitted by the radium may be made with the aid of the ice calorimeter of Bunsen. When a tube of radium is placed in the calorimeter, there is observed a continual evolution of heat, which ceases when the radium is withdrawn. Measurements made with a sample of radium which had been prepared a long time previously indicated that each gram of radium gives off about 80 small calories per hour. Thus radium gives off sufficient heat in an hour to melt its own weight of ice. This evolution of heat produces no change in the appearance of the salt, nor can any ordinary chemical reaction be pointed out as the source of the heat evolved.

It has been shown that a radium salt when first prepared gives off comparatively little heat, and that the heating increases steadily toward a maximum amount, which is not fully attained at the end of a month.

When a salt of radium is dissolved in water and the solution is placed in a sealed tube, the quantity of heat evolved by the solution is at first feeble, but increases and tends toward a constant value, which is attained after about a month. When this constant state is reached, the salt in solution evolves the same amount of heat which it would give if in a solid state.

The amount of heat given out by radium at different temperatures may be determined by causing it to boil a liquefied gas, and measuring

[a] Curie and Laborde, C. R., March 16, 1903.

the volume of gas evolved. This experiment may be performed with methyl chloride (at −21° C.). Professor Dewar and M. Curie have conducted such experiments with liquid oxygen (at −180° C.) and liquid hydrogen (at −292° C.). This last liquid serves the purpose particularly well. A tube A (fig. 7) (closed at the lower end and inclosed by a vacuum heat insulator of Dewar) contains a little liquid hydrogen H. A tube tt′ serves to convey the gas to be collected over water in the inverted graduate E. The tube A and its insulator are plunged into a bath of liquid hydrogen H′. In these conditions no evolution of gas is produced in A. But when a tube a containing 0.7 gram of radium bromide is placed in the hydrogen in the tube A, the gas is continually evolved at the rate of 73 cubic centimeters per minute.

VI.

The radiations of radium provoke many chemical reactions. They act upon the substances employed in photography in the same manner as light. Glass is tinged violet or brown, and salts of the alkalies are colored yellow, violet, blue, or green. Under the action of the rays paraffin, paper, and celluloid turn yellow, paper becomes brittle, and ordinary phosphorus is transformed into the red variety. In general, bodies phosphorescent under the action of radium rays undergo a transformation, and at the same time their phosphorescence tends to disappear. Finally it has been shown that the presence of radium salts promotes the formation of ozone in the air.

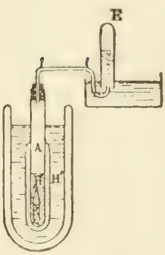

FIG. 7.—Boiling liquid hydrogen by radium.

VII.

The radiations of radium produce various physiological effects.

A salt of radium contained in an opaque tube of metal or pasteboard produces a sensation of light upon the eye. This may be shown by placing the tube of radium before the closed eye or against the temple. The eye then becomes phosphorescently luminous under the influence of the rays and light is perceived within the eye itself.[a]

Radium acts upon the skin so that if one holds a tube of radium in the hand for some minutes, though no particular sensation is felt at the time, after fifteen or twenty days an inflammation is produced and then the skin sloughs off at the place where the radium was applied. If the action of radium is continued long enough a sore is formed which may take months to heal. The action of radium rays on the skin is analogous to that of the Röntgen rays. It has been attempted to utilize it in the treatment of lupus and cancer.[b]

[a] Giesel, Naturforscherversammlung, München, 1899. Himstedt and Nagel, Ann. der Physik, Vol. IV, 1901.

[b] Walkoff, Phot. Rundschau, Oct. 1900. Giesel, Berichte d. Deutsche Chem. Gesell., Vol. XXIII. Becquerel and Curie, C. R., Vol. CXXXII, p. 1289.

The action of radium rays on nervous centers may result in paralysis or death. They seem to act with particular intensity on living tissues in the process of growth.[a]

VIII.

When any solid body is placed near a salt of radium it acquires the radiant properties of radium, or in other words becomes radio-active. This induced radio-activity persists for some time after the body is removed from the presence of the radium, but it becomes steadily feebler and diminishes about half in each half hour till it disappears. This phenomenon is produced in a particularly intense and regular fashion if the solid body is placed with the radium salt in a closed vessel, and it is advantageous to employ a solution of radium salt rather than the salt in the solid form.[b]

A salt of radium is placed at A (fig. 8) in a glass reservoir which communicates by tubes t and t′ with two other glass reservoirs B and C, from which air may be exhausted. It may be shown that the walls of the reservoirs B and C become radio-active and emit Becquerel rays analogous to those emitted ordinarily by radium itself, while on the contrary the solution of radium emits very little radiation, so that the radio-activity becomes, as it were, exteriorized.

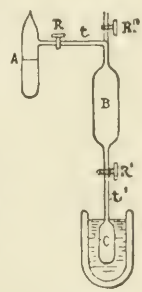

Fig. 8—Induced radio-activity.

This phenomenon is well exhibited in other gases than air, and is independent of the presence of the gas. The radio-activity is communicated from one place to another by a sort of conduction through the gas, and may even be propagated from one reservoir to another through a capillary tube. Gas which has been in contact with radium, therefore, acquires the property of imparting radio-activity to solids. The gas is itself radio-active, but does not emit rays which are very penetrating. Rays emitted by gases are not transmitted through the walls of a glass receiver.

When the gas thus modified is removed far from the radium it retains its properties for a long time, and continues to emit Becquerel rays of slight penetration and to impart radio-activity to solids. But its activity from either point of view diminishes by half in each four days till it disappears.

Rutherford supposes that radium continually emits a radio-active gaseous substance which diffuses in space and provokes the induced radio-activity. He gives to this hypothetical substance the name of radium emanation and believes that it is to be found in a mixed condition in gases in the vicinity of radium. Without necessarily admit-

[a] Danyz, C. R., Feb. 16, 1903. G. Bohn, C. R , April 27, 1903.

[b] M. and Mme. Curie, C. R., Nov. 6, 1899. Curie and Debierne, C. R., Mar. 4, 1901, July 29, 1901, Mar. 25, 1901.

ting the material nature of the emanation, this expression may be employed to designate the special radio-active energy stored in the gas.[a]

Air charged with the emanation provokes phosphorescence in bodies which are immersed in it. Glass (especially Thuringian glass) gives a beautiful white or green phosphorescence. Sidot's sulphide of zinc becomes excessively brilliant under the action of the emanation.[b] This experiment may be tried with the apparatus shown in fig. 8. The cock R being closed, the radio-active emanation which is emitted by the solution in A saturates the air above the solution. When the emanation has accumulated in A for some days the reservoirs B and C, whose inner walls are coated with zinc sulphide, are exhausted. The cock R″ is then closed and R opened, so that the air charged with the emanation expands suddenly into the reservoirs B and C, which immediately become luminous.

Radium emanation comports itself as a gas from many points of view. Thus it is shared in the same proportions as a gas would be by two communicating reservoirs. It diffuses in air according to the law of diffusion of gases, and has a coefficient of diffusion not far from that of carbonic acid gas in air.[c]

Messrs. Rutherford and Soddy discovered that the emanation has the property of condensing at the temperature of liquid air.[d] The effects of such condensation may be shown with the apparatus pictured in fig. 8. The cock R″ being closed, and the emanation being diffused throughout the apparatus, as at the conclusion of the experiment last described, the reservoirs B and C (which are covered within with phosphorescent zinc sulphide) are luminous. On closing the cock R and plunging the reservoir C in liquid air, at the end of a half hour, it is seen that the reservoir B has lost its luminosity, while the reservoir C is still bright. Thus it is seen that the emanation has quitted the reservoir B and become condensed in the cooled portion of the reservoir C. However, the luminosity of C is not very intense, since the phosphorescence of sulphide of zinc is more feeble at the temperature of liquid air than at ordinary temperatures; but by closing the cock R′, which interrupts communication between the two reservoirs, and again bringing C to the temperature of the surroundings, it becomes again brilliantly illuminated, while B remains dark. Thus the emanation which at first filled the two reservoirs is now all contained in C.

The preceding experiments tend to convince us that the emanation is analogous to ordinary gases, but up to the present time the hypothesis of the existence of such a gas rests wholly on the manifestations

[a] Rutherford, Phil. Mag., 1900, 1901, 1902. Numerous articles—Dorn, Abh. Naturfrshgesel. Halle, June, 1900; P. Curie, C. R. Nov. 17, 1902, Jan. 26, 1903.

[b] Curie and Debierne, C. R., Dec. 2, 1901.

[c] Curie and Danne, C. R., 1903.

[d] Rutherford and Soddy, Phil. Mag., May, 1903.

of radio-activity. It may be remarked that, contrary to the behavior of ordinary gases, the emanation spontaneously disappears when contained for a sufficient time in a sealed tube.

The quantity of emanation diminishes by a half in four days, and this time constant is characteristic of the emanation of radium.

IX.

Having briefly enumerated the principal properties of radium, it is proper to recall in a few words the origin of its discovery, in which Mme. Curie has had a very great share.[a]

Experiments with the substances separated from uranium and thorium had showed that the radio-activity is an atomic property which always accompanies the atoms of these simple substances. The radio-activity of a complex substance is generally greater the larger the proportion of the radio-active metal contained in the compound. Certain ores of uranium, as pitchblende, chalcolite, and carnotite, have, however, a radio-activity superior to that of metallic uranium. We therefore questioned whether these minerals might not contain in minute proportion some substances still unrecognized and far more radio-active than uranium, and we searched by chemical methods for the hypothetical substances, always guided by the radio-activity of the substance treated.

Our anticipations were verified by the results. Pitchblende contains new radio-active substances, but in an excessively minute proportion. A ton of pitchblende, for example, contains a quantity of radium on the order of one-tenth of a gram. In these conditions the preparation of radium salts is very tedious and costly. A ton of ore furnishes some kilograms of radiferous barium bromide, from which the radium is extracted by a series of fractionations.

During the separation of radium, Demarçay, whose recent death is much deplored, was so good as to examine spectroscopically the products which we prepared. This cooperation was most valuable to us, for at the conclusion of our research the spectrum analysis confirmed our anticipations and furnished the proof that the radio-active barium which we had separated from pitchblende contained a new element. Demarçay made the first investigation of the spectrum of radium.[b]

Radium has a very sensitive spectrum reaction—indeed, quite as sensitive as that of barium. The presence of radium may be detected spectroscopically in radiferous barium containing only one ten-thousandth of radium; but the radio-activity of radium gives a reaction 10,000 times as sensitive still. An electrometer ordinarily well insulated enables the observer to detect readily the presence of radium

[a] Mme. Curie, Thèse à la Faculté des Sciences, Paris, 1903.

[b] Demarçay, C. R., December, 1898, and July, 1900.

when contained in a mixture of inactive substance in the proportion of 1 to 100,000,000.

Radium is a higher homologue of barium in the series of alkaline earth metals. Its atomic weight has been determined by Madame Curie to be 226.

While thus a near neighbor to barium, it is not found, even as a trace, in the ordinary mineral sources of barium, and only accompanies it in the uranium ores, which fact is of great theoretical importance.

X.

Radium therefore gives us an example of a body which, while remaining in the same state, evolves continuously a considerable amount of energy. This fact is apparently in contradiction to the fundamental principles of energetics, and various hypotheses have been put forward to avoid this contradiction.

Among these hypotheses we may consider two which were made at the beginning of tne studies of radio-activity.[a]

In the first hypothesis it is assumed that radium is an element in process of evolution. It must then be admitted that the evolution is extremely slow, so that no appreciable change of state is discernable in the course of several years, for the energy which is disengaged in the course of a year corresponds with an insignificant transformation of matter. It would appear natural to suppose that the quantity of energy put in play in the transformation of atoms is considerable.

The second hypothesis assumes the existence in space of radiations still unknown and inaccessible to our senses. Radium might be assumed to be capable of absorbing the energy of these hypothetical rays and transforming it into radio-active energy.

The two hypotheses which we have mentioned seem not incompatible.

Since the delivery of this lecture there was made (June 19, 1903) a discovery of great importance by Messrs. Ramsay and Soddy. They found that the emanation of radium as it disappears gives place to the production of helium gas, whose presence can be recognized by spectrum analysis. It seems, then, that we are here brought face to face for the first time with the formation of an element. It is possible that radium is an unstable chemical element, and that helium is produced as one of the products of its disaggregation.

[a] Mme. Curie, Revue général des Sciences, Jan. 30, 1899.

RADIUM.[a]

By J. J. Thomson.

The discovery by Monsieur and Madame Curie that a sample of radium gives out sufficient energy to melt half its weight of ice per hour has attracted attention to the question of the source from which the radium derives the energy necessary to maintain the radiation: this problem has been before us ever since the original discovery by Becquerel of the radiation from uranium. It has been suggested that the radium derives its energy from the air surrounding it; that the atoms of radium possess the faculty of abstracting the kinetic energy from the more rapidly moving air molecules while they are able to retain their own energy when in collision with the slowly moving molecules of air. I can not see, however, that even the possession of this property would explain the behavior of radium; for imagine a portion of radium placed in a cavity in a block of ice. The ice around the radium gets melted. Where does the energy for this come from? By the hypothesis there is no change in the energy of the air radium system in the cavity, for the energy gained by the radium is lost by the air, while heat can not flow into the cavity from outside, for the melted ice around the cavity is hotter than the ice surrounding it.

Another suggestion which has been made is that the air is traversed by a very penetrating kind of Becquerel radiation, and that it is the absorption of this radiation that gives the energy to the radium. We have direct evidence of the existence of such radiation, for McClennan and Burton have recently shown that the ionization of a gas inside a closed vessel is diminished by immersing the vessel in a large tank full of water, suggesting that part, at any rate, of the ionization of the gas is due to a radiation which could penetrate the walls of the vessel, but which was stopped to an appreciable extent by the water. To explain the heating effect observed with radium, the absorption of this radiation by radium must be on an altogether different scale from its absorption by other metals. As no direct experiments have been made on radium, it is possible that this may be the case; it is not, however, what we should expect from the experiments which have been made on the absorption of this radiation by other metals, for these experiments have shown that the absorption depends solely upon the density

[a] Reprinted from Nature, London, No. 1748, vol. 67, Apr. 30, 1903, pp. 601-602.

of the absorbing substance and not upon its chemical nature or physical state. If this law hold for radium, the absorption by it would be on the same scale as the absorption by lead or gold and altogether too small to explain the observed effects. We are thus led to seek for some other explanation. I think that the absence of change in the radium has been assumed without sufficient justification; all that the experiments justify us in concluding is that the rate of change is not sufficiently rapid to be appreciable in a few months. There is, on the other hand, very strong evidence that the substances actually engaged in emitting these radiations can only keep up the process for a short time; then they die out, and the subsequent radiation is due to a different set of radiators.

Take, for example, Becquerel's experiment when he precipitated barium from a radio-active solution containing uranium, and found that the radio-activity was transferred to the precipitate, the solution not being radio-active; after a time, however, the radio-active precipitate lost its radio-activity, while the solution of uranium regained its original vigor. The same thing is very strikingly shown by the remarkable and suggestive experiments made by Rutherford and Soddy on thorium. They separated ordinary radio-active thoria into two parts, transferring practically all the radio-activity to a body called by them "thorium X," the mass of which was infinitesimal in comparison with that of the original thoria. The thorium X thus separated lost in a few days its radio-activity, while the original thoria in the same time again became radio-active. This seems as clear a proof as we could wish for that the radio-activity of a given set of molecules is not permanent. The same want of permanence is shown by the radio-active emanations from thorium and radium, and by the induced radio-activity exhibited by bodies which have been negatively electrified and exposed to these emanations or to the open air; in all these cases the radio-activity ceases after a few days. I have recently found that the water from deep wells in Cambridge contains a radio-active gas, and that this gas after being liberated from the water gradually loses its radio-activity. The radio-activity of polonium, too, is known not to be permanent.

The view that seems to me to be suggested by these results is that the atom of radium is not stable under all conditions, and that among the large number of atoms contained in any specimen of radium there are a few which are in the condition in which stability ceases and which pass into some other configuration, giving out as they do so large a quantity of energy. I may, perhaps, make my meaning clearer by considering a hypothetical case. Suppose that the atoms of a gas X become unstable when they possess an amount of kinetic energy 100 times, say, the average kinetic energy of the atoms at the temperature of the room. There would, according to the Maxwell-Boltzmann law

of distribution, always be a few atoms in the gas possessing this amount of kinetic energy; these would by hypothesis break up. If in doing so they gave out a large amount of energy in the form of Becquerel radiation, the gas would be radio-active and would continue to be so until all its atoms had passed through the phase in which they possessed enough energy to make them unstable. If this energy were 100 times the average energy it would probably take hundreds of thousands of years before the radio-activity of the gas was sensibly diminished. Now in the case of radium, just as in the gas, the atoms are not all in identical physical circumstances, and if there is any law of distribution like the Maxwell-Boltzmann law, there will on the above hypothesis, be a very slow transformation of the atoms accompanied by a liberation of energy. In the hypothetical case we have taken the possession of a certain amount of kinetic energy as the criterion for instability. The argument will apply if any other test is taken.

It may be objected to this explanation that if the rate at which the atoms are being transformed is very slow, the energy liberated by the transformation of a given number of atoms must be very much greater than that set free when the same number of atoms are concerned in any known chemical combination. It must be remembered, however, that the changes contemplated on this hypothesis are of a different kind from those occurring in ordinary chemical combination. The changes we are considering are changes in the configuration of the atom, and it is possible that changes of this kind may be accompanied by the liberation of very large quantities of energy. Thus, taking the atomic weight of radium as 225, if the mass of the atom of radium were due to the presence in it of a large number of corpuscles, each carrying the charge of 3.4 by 10^{-10} electrostatic units of negative electricity, and if this charge of negative electricity were associated with an equal charge of positive, so as to make the atom electrically neutral, then if these positive and negative charges were separated by a distance of 10^{-8} cm., the intrinsic energy possessed by the atom would be so great that a diminution of it by 1 per cent would be able to maintain the radiation from radium as measured by Curie for 30,000 years.

Another point to be noted is that the radiation from a concentrated mass of radium may possibly be very much greater than that from the same mass when disseminated through a large volume of pitchblende; for it is possible that the radiation from one atom may tend to put the surrounding atoms in the unstable state. If this were so, more atoms would in a given time pass from the one state to the other if they were placed so as to receive the radiation from their neighbors than if they were disseminated through a matrix which shielded each radium atom from the radiation given out by its neighbors.

EXPERIMENTS IN RADIO-ACTIVITY AND THE PRODUCTION OF HELIUM FROM RADIUM.[a]

By Sir William Ramsay and Mr. Frederick Soddy.

(1) EXPERIMENTS ON THE RADIO-ACTIVITY OF THE INERT GASES OF THE ATMOSPHERE.

Of recent years many investigations have been made by Elster and Geitel, Wilson, Strutt, Rutherford, Cooke, Allen, and others on the spontaneous ionization of the gases of the atmosphere and on the excited radio-activity obtainable from it. It became of interest to ascertain whether the inert monatomic gases of the atmosphere bear any share in these phenomena. For this purpose a small electroscope contained in a glass tube of about 20 cubic centimeters capacity, covered in the interior with tin foil, was employed. After charging, the apparatus if exhausted retained its charge for thirty-six hours without diminution. Admission of air caused a slow discharge. In similar experiments with helium, neon, argon, krypton, and xenon, the last mixed with oxygen, the rate of discharge was proportional to the density and pressure of the gas. This shows that the gases have no special radio-activity of their own, and accords with the explanation already advanced by these investigators, that the discharging power of the air is caused by extraneous radio-activity.

Experiments were also made with the dregs left after liquefied air had nearly entirely evaporated, and again with the same result: no increase in discharging power is produced by concentration of a possible radio-active constituent of the atmosphere.

(2) EXPERIMENTS ON THE NATURE OF THE RADIO-ACTIVE EMANATION FROM RADIUM.

The word emanation, originally used by Boyle ("substantial emanations from the celestial bodies"), was resuscitated by Rutherford to designate definite substances of a gaseous nature continuously produced from other substances. The term was also used by Russell ("emanation from hydrogen peroxide") in much the same sense. If

[a] By Sir William Ramsay, K. C. B., F. R. S., and Mr. Frederick Soddy. Received at the Royal Society July 28. Reprinted from Nature, London, August 13, 1903, No. 1763, vol. 68, pp. 354, 355.

the adjective "radio-active" be added, the phenomenon of Rutherford is distinguished from the phenomena observed by Russell. In this section we are dealing with the emanation, or radio-active gas obtained from radium. Rutherford and Soddy investigated the chemical nature of the thorium emanation (Phil. Mag., 1902, p. 580) and of the radium emanation (ibid., 1903, p. 457), and came to the conclusion that these emanations are inert gases which withstand the action of reagents in a manner hitherto unobserved except with the members of the argon family. This conclusion was arrived at because the emanations from thorium and radium could be passed without alteration over platinum and palladium black, chromate of lead, zinc dust, and magnesium powder, all at a red heat.

We have since found that the radium emanation withstands prolonged sparking with oxygen over alkali, and also, during several hours, the action of a heated mixture of magnesium powder and lime. The discharging power was maintained unaltered after this treatment, and inasmuch as a considerable amount of radium was employed it was possible to use the self-luminosity of the gas as an optical demonstration of its persistence.

In an experiment in which the emanation mixed with oxygen had been sparked for several hours over alkali, a minute fraction of the total mixture was found to discharge an electroscope almost instantly. From the main quantity of the gas the oxygen was withdrawn by ignited phosphorus, and no visible residue was left. When, however, another gas was introduced, so as to come into contact with the top of the tube, and then withdrawn, the emanation was found to be present in it in unaltered amount. It appears, therefore, that phosphorus burning in oxygen and sparking with oxygen has no effect upon the gas so far as can be detected by its radio-active properties.

The experiments with magnesium lime were more strictly quantitative. The method of testing the gas before and after treatment with the reagent was to take one two-thousandth part of the whole mixed with air, and after introducing it into the reservoir of an electroscope to measure the rate of discharge. The magnesium-lime tube glowed brightly when the mixture of emanation and air was admitted, and it was maintained at a red heat for three hours. The gas was then washed out with a little hydrogen, diluted with air, and tested as before. It was found that the discharging power of the gas had been quite unaltered by this treatment.

The emanation can be dealt with as a gas; it can be extracted by aid of a Töpler pump; it can be condensed in a U-tube surrounded by liquid air, and when condensed it can be "washed" with another gas which can be pumped off completely, and which then possesses no luminosity and practically no discharging power. The passage of the emanation from place to place through glass tubes can be followed by

the eye in a darkened room. On opening a stopcock between a tube containing the emanation and the pump, the slow flow through the capillary tube can be noticed; the rapid passage along the wider tubes; the delay caused by the plug of phosphorus pentoxide, and the sudden diffusion into the reservoir of the pump. When compressed, the luminosity increased, and when the small bubble was expelled through the capillary it was exceedingly luminous. The peculiarities of the excited activity left behind on the glass by the emanation could also be well observed. When the emanation has been left a short time in contact with the glass, the excited activity lasts only for a short time; but after the emanation has been stored a long time the excited activity decays more slowly.

The emanation causes chemical change in a similar manner to the salts of radium themselves. The emanation pumped off from 50 milligrams of radium bromide after dissolving in water, when stored with oxygen in a small glass tube over mercury, turns the glass distinctly violet in a single night; if moist the mercury becomes covered with a film of the red oxide, but if dry it appears to remain unattacked. A mixture of the emanation with oxygen produces carbon dioxide when passed through a lubricated stopcock.

(3) OCCURRENCE OF HELIUM IN THE GASES EVOLVED FROM RADIUM BROMIDE.

The gas evolved from 20 milligrams of pure radium bromide (which we are informed had been prepared three months) by its solution in water and which consisted mainly of hydrogen and oxygen (cf. Giesel, Ber., 1903, 347) was tested for helium, the hydrogen and oxygen being removed by contact with a red-hot spiral of copper wire, partially oxidized, and the resulting water vapor by a tube of phosphorus pentoxide. The gas issued into a small vacuum tube which showed the spectrum of carbon dioxide. The vacuum tube was in train with a small U-tube, and the latter was then cooled with liquid air. This much reduced the brilliancy of the CO_2 spectrum, and the D_3 line of helium appeared. The coincidence was confirmed by throwing the spectrum of helium into the spectroscope through the comparison prism, and shown to be at least within 0.5 of an Angström unit.

The experiment was carefully repeated in apparatus constructed of previously unused glass with 30 milligrams of radium bromide, probably four or five months old kindly lent us by Professor Rutherford. The gases evolved were passed through a cooled U-tube on their way to the vacuum tube, which completely prevented the passage of carbon dioxide and the emanation. The spectrum of helium was obtained, and practically all the lines were seen, including those at 6677, 5876, 5016, 4932, 4713, and 4472. There were also present three lines of approximate wave lengths, 6180, 5695, 5455, that have not yet been identified.

On two subsequent occasions the gases evolved from both solutions of radium bromide were mixed, after four days' accumulation, which amounted to about 2.5 cubic centimeters in each case, and were examined in a similar way. The D_3 line of helium could not be detected. It may be well to state the composition found for the gases continuously generated by a solution of radium, for it seemed likely that the large excess of hydrogen over the composition required to form water, shown in the analysis given by Bodländer (Ber., loc. cit.), might be due to the greater solubility of the oxygen. In our analyses the gases were extracted with the pump, and the first gave 28.6, the second 29.2, per cent of oxygen. The slight excess of hydrogen is doubtless due to the action of the oxygen on the grease of the stopcocks, which has been already mentioned. The rate of production of these gases is about 0.5 cubic centimeter per day for 50 milligrams of radium bromide, which is more than twice as great as that found by Bodländer.

(4) PRODUCTION OF HELIUM BY THE RADIUM EMANATION.

The maximum amount of the emanation obtained from 50 milligrams of radium bromide was conveyed by means of oxygen into a U-tube cooled in liquid air, and the latter was then extracted by the pump. It was then washed out with a little fresh oxygen, which was again pumped off. The vacuum tube sealed onto the U-tube, after removing the liquid air, showed no trace of helium. The spectrum was apparently a new one, probably that of the emanation, but this has not yet been completely examined, and we hope to publish further details shortly. After standing from July 17 to 21, the helium spectrum appeared, and the characteristic lines were observed identical in position with those of a helium tube thrown into the field of vision at the same time. On July 22 the yellow, the green, the two blues, and the violet were seen, and in addition the three new lines also present in the helium obtained from radium. A confirmatory experiment gave identical results.

We wish to express our indebtedness to the research fund of the chemical society for a part of the radium used in this investigation.

THE N RAYS OF M. BLONDLOT.

By C. G. Abbot.

[The so-called "N rays," recently described by M. Blondlot and others, have too respectable an introduction to the scientific public in the Comptes Rendus of the Institute of France (from which this paper has been chiefly abstracted) and have attracted too wide attention to justify an omission of all notice of them in this place. It nevertheless seems proper to state here that the experiments on which they rest are not universally deemed conclusive, and that final judgment upon them may be suspended until the appearance of still further evidence.—Note by S. P. Langley.]

DISCOVERY.

In the early part of the year 1903 M. Blondlot, professor of physics at the University of Nancy, was carrying on some studies of the X rays to discover if these could be polarized. He found that a convenient method of recognizing the presence and possible polarization of these rays consisted in the employment of a small electric sparking device. Two sharpened wires, communicating inductively with the terminals of a Ruhmkorff coil, were so nearly approached that feeble sparks continually passed between them, and upon bringing this sparking device near a source of X rays the luminosity of the sparks was found to increase. M. Blondlot at first thought he detected by his experiments a considerable degree of polarization in the X rays, but a little later he decided that it was not the X rays themselves which gave the appearance of polarization, but a new kind of rays heretofore unrecognized. In his first experiments with these rays their source was a Crookes tube provided with a thin covering of aluminum to cut off the light. The rays which traversed the aluminum then passed through a rectangular opening in a sheet of lead and fell upon the little sparking device already mentioned. It was found that only when the line of sparks flew in a certain direction, as compared with the slit in the leaden sheet, could the maximum brightness be observed, and this direction for maximum brightness was altered when a substance which rotates the plane of polarization of light was introduced.

The experiments on polarization suggested to M. Blondlot the possibility that the new rays might also be refracted. He tested this by interposing a quartz prism, and found that in fact the rays were now diverted from a straight line, so that he was obliged to carry the sparking device to one side in order to reach a point of increased luminosity. By means of a quartz lens the fact of the refraction of the rays was further verified, and following this it was found that the rays could be reflected regularly and diffusely, just as is the case with ordinary light. As polarization, refraction, and reflection are not qualities of X-rays, but are essentially qualities of ordinary light, M. Blondlot drew the conclusion that he was now dealing with radiation propagated by waves in the ether in essentially the same manner as ordinary light. This new type of rays he found to be transmitted by wood, paper, aluminum, and many other metals, but to produce no direct effect upon the eye, the photographic plate, or a phosphorescent screen, and he was at first unable to recognize them excepting by means of the little sparking device.

The experiments with refraction in prisms and lenses had indicated that the index of refraction of these rays in quartz was very high and indeed exceeding 2. Professor Rubens had not long before discovered rays of great wave length for which the index of refraction in quartz was about 2.18. This similarity of refractive index led M. Blondlot at first to think that perhaps he was now dealing with a type of radiation belonging to the extreme infra-red, and as Rubens had employed a Welsbach lamp as a source of the radiations he had measured, M. Blondlot sought to determine if these new rays were also emitted by this source. Shielding the lamp which he employed by an iron covering having a small aluminum window, he was able to detect the presence of the rays in question in its radiation by the aid of the small sparking device. When the quartz lens was used to form an image of the source, the rays appeared not to be homogeneous, but to contain at least four different varieties whose indices of refraction were, respectively, 2.94, 2.62, 2.44, and 2.29. With the exception of lead, rock salt, platinum, and water, the rays were found to be transmissible by moderate thicknesses of many different substances, including tin foil, copper, aluminum, steel, silver, gold, paraffin, black rubber, and others.

SOURCES OF THE RAYS AND METHODS EMPLOYED IN THEIR RECOGNITION.

M. Blondlot now gave a name to these rays, calling them N rays, after the city of Nancy, in which he lives. He claims to detect their presence in the emission of luminous gas flames, as well as in the sources already mentioned, but he failed to find them in the emission of a Bunsen burner. The Nernst lamp is spoken of as a specially intense source of them.

Other methods of recognizing the rays were now introduced, for M. Blondlot was led to inquire whether the sparking device acted as a sign of their presence by virtue of its electrical properties or by virtue merely of its emission of light. Accordingly he used a small blue flame instead of the device, and found with it also an increased luminosity when placing it in the focus of the rays. A little later he found that phosphorescent substances, though not excited directly by the rays, yet if first made feebly luminous by ordinary light were raised to a higher luminosity when exposed to the N rays. In later experiments it appeared that a surface feebly illuminated by reflected light became brighter under the influence of N rays. Still more remarkable, he found that if the N rays fell only on the eye of the observer, and not on the object observed, the latter was nevertheless made to appear more luminous, though the N rays themselves produce no sensation of light. Photography failed as a direct method of observing the rays, but he used it indirectly to note the increased luminosity of the spark, the blue flame, or the phosphorescent surface which was employed to recognize the presence of the rays. The accompanying figure, taken from the Comptes Rendus of February 22, 1904, shows an example of this indirect photographic method. Experiments with the most sensitive apparatus failed to record any sensible heating produced by the N rays.

M. Blondlot makes the following general remark concerning the observation of the N rays:

The ability to recognize slight variations of luminous intensity varies very much between different persons. Some see at the first glance, without any difficulty, the augmentation which the N rays produce in the brightness of a small luminous source, while to others these changes are very near the limit which they can distinguish, and it is only after some experience that they are able to be sure of having observed the phenomenon. The feebleness of these effects and the delicacy of the observation ought not, however, to arrest our study of these heretofore unknown radiations. I have found recently that the Welsbach burner may be advantageously replaced as a source by the Nernst lamp with no glass covering, for this latter gives forth the N rays with greater intensity, and thus with a 200-watt lamp, for example, the phenomena are so marked that they may be easily observed.

N RAYS FROM THE SUN.

The following simple experiment is given by the discoverer to show the existence of N rays in the solar beam:

A completely darkened chamber is furnished with a window exposed directly to the sun's rays, and this window is closed by an oak shutter at least half an inch thick, so that no ordinary light can possibly penetrate into the room. Behind this shutter, at about a meter distance, for example, is placed a small glass tube containing a phosphorescent substance—sulphide of calcium, for example—which has previously been exposed to light and become feebly luminescent. If, now, in the beam of the sun, which we suppose to pass through the wooden shutter and fall upon the phosphorescent tube, we interpose a screen of lead, or even simply the hand of the

observer, though at considerable distance from the tube, the brightness of the phosphorescence is seen to diminish, and upon removing the obstacle the brightness again increases. The only precaution which it is necessary to take is to employ a tube only slightly phosphorescent, but it is advantageous to place behind it a black paper, so that the interposition of the screen produces no change whatever in the background against which one sees the tube. The variations of brightness are most easy to observe near the boundaries of the luminous spot formed upon the black background by the phosphorescent body, and when the N rays are intercepted these contours lose their sharpness and regain it when the screen is removed. Sometimes the variations of brightness are not instantly recognized. Interposition in the path of the beam of several sheets of aluminum, of cardboard, and even of a board of oak more than an inch thick, does not prevent the effect, so that all possibility of the action of any ordinary radiation is of course excluded. A thin sheet of water, however, entirely arrests the rays, and thin clouds passing before the sun considerably diminish their action.

WAVE LENGTH OF THE RAYS IN QUESTION.

M. Blondlot, as we have seen, was at first inclined to think that his rays belonged in the extreme infra-red spectrum, but more recently he has described measures of their wave length by means of the diffraction grating which lead him to the opposite conclusion. He employed a spectroscope with aluminum prism to separate the several different species of N rays emitted by a Nernst lamp, and then estimated their wave length by means of several different diffraction gratings having, respectively, 50, 100, and 200 lines to the millimeter. The following table contains the results of his measures:

Indices of refraction in aluminum.	Wave lengths.			
	Grating employed.			Probable values deduced from the preceding.
	Rulings 0.02 mm.	Rulings 0.01 mm.	Rulings 0.5 mm.	
	μ	μ	μ	μ
1.04	0.00813	0.00795	0.00839	0.00815
1.19	.00930	.01020	.01050	.00990
1.40	.01170			.01170
1.68	.01460			.01460
1.85	.01760	.01710	.01840	.01760

Thus it appears that the N rays belong far beyond the previously studied ultraviolet, and have a wave length only one-tenth that of the rays with which Doctor Schumann has been working with his vacuum spectograph. It is somewhat extraordinary that the N rays should so readily traverse thicknesses of the air and other substances, which would entirely arrest the ultraviolet rays examined by Doctor Schumann, but, as is the case in other regions of the spectrum, it may be that the air has here special bands of great absorption, in one of which Doctor Schumann's rays lie, and that beyond this region there are other parts of the spectrum where the air is again transparent. Another curious thing about the measures just given is that the aluminum

Without N-rays. With N-rays, produced by two large lime lights.

Without N-rays. With N-rays, produced by a Nernst lamp.

PHOTOGRAPHS OF INCREASED LUMINOSITY PRODUCED BY N-RAYS.

prism appears to be anomalously refracting; in other words, its indices of refraction increase rather than decrease with increasing wave length of the rays. M. Blondlot suggests that the augmentation of brilliancy observed in a small luminous source under the action of the N rays may be attributed to a transformation of these radiations into luminous ones in conformity to the law of Stokes.

STORING UP OF THE N RAYS.

M. Blondlot finds that many substances are able to store up the N rays and emit them for some time after having been subjected to the influence of a source. This property, it will be seen, is similar to the phenomenon of phosphorescence which is observed with ordinary light. Among the substances which appear to store up the N rays are quartz, Iceland spar, fluorspar, glass, and many others. Aluminum, wood, paper, and paraffin, on the other hand, do not appear to possess this property of storing up N rays to any very appreciable extent. The phenomenon is so general that a large portion of the bodies upon which the sun's rays fall are said by M. Blondlot to become saturated with the rays and to give them out undiminished in some cases as long as four days after they have been removed from the influence of the sun.

N RAYS PRODUCED BY MECHANICAL PROCESSES.

It appeared that compression and other distortions of metals, wood, glass, rubber, etc., caused these substances to emit N rays while under such mechanical constraint. Crystalline substances, tempered steel, and some other bodies possessing special internal structure, are stated to be spontaneous and permanent sources of N rays. As an illustration of the permanence with which this property remains associated with such substances, M. Blondlot mentions that a sword found in an ancient sepulcher dating from the Merovingian epoch, was found to give out the N rays strongly. It thus appears that the emission of the N rays by tempered blades of steel may continue for centuries without becoming enfeebled, and as regards continuous emission, therefore, the N rays may be compared with the radiation of uranium, radium, polonium, and other sources of Becquerel rays, although, of course, in other respects the two kinds of radiations are entirely different.

EMISSION OF N RAYS BY THE HUMAN BODY.

M. Charpentier, while repeating in his laboratory many of the experiments of M. Blondlot on the production and observation of N rays, noted that the luminosity of phosphorescent substances used to detect the presence of the rays appeared to increase when the observer approached these phosphorescent substances. Continuing

the studies which this observation led him to pursue, he found that the increase of brightness was most considerable in the vicinity of a muscle, and was greatest when the muscle was strongly contracted. Nerves and nervous centers were afterwards found to produce similar effects, and he was even able to follow in this manner the course of certain nerves beneath the skin. These experiments suggested to him that the human body, at least some portions of it, might be emitting N rays, and he found that the emissions observed passed readily through aluminum, paper, and other substances classed as transparent to the N rays, and that they were arrested by lead and moistened paper which had been used by M. Blondlot as screens. The rays were further found to be reflected and refracted, and could be brought to a focus by the aid of convex lenses, and appeared to have about the same indices of refraction as the N rays themselves. It seemed possible, however, that the human body acted merely as a reservoir, storing up the rays like some other substances in which such action had been observed by M. Blondlot, but M. Charpentier states that after continuing nine hours in complete darkness the rays were still emitted by the body, though perhaps a greater sensitiveness of the eye under these conditions may have made it more easy to recognize them. However, M. Charpentier is of the opinion that the human body certainly emits N rays, and especially in those parts of it which are in active use.

From later experiments it was concluded that the lower animals, such as the monkey and others, are active sources of the N rays, and that here, as in man, the principal seat of the emission is in the muscles and nerves. It was not alone the warm-blooded animals which appeared to give rise to emission, but also the cold-blooded—frogs and others. As in the case of metals and other substances experimented upon by M. Blondlot, mechanical constraint, such as the compression of nerves and muscles, greatly augmented the luminous effects. In order to localize the observations in a convenient manner, M. Charpentier uses a narrow lead tube from 2 to 4 inches in length, of which one end is placed in contact with the body to be examined and the other contains the phosphorescent substance used as the indicator. He states that he can thus trace out the regions of the brain which are active in special functions, such as the "center of Broca," reputed to be the seat of articulate language.

It appears from Charpentier's later experiments that the physiological emissions are not exclusively composed of N rays, but include other kinds of radiation differing in some degree in their properties from those which have been found associated with the N rays.

TRANSMISSION OF THE N RAYS ALONG WIRES.

In the course of M. Charpentier's experiments he found that the rays emitted by the human body are capable of being transmitted not only in the air, but along wires of metal, such as copper or aluminum. This extraordinary discovery has been explained by M. Bichat, who observes that this method of transmission may be compared to the repeated reflections of ordinary light within a long glass tube. His experiments indicated first of all that the wire itself was certainly the conductor of the rays, and not the medium in which it was placed, for upon immersing the wire in water the conductivity remained undiminished. It was necessary, moreover, that the wire should be of good transmitting material, for leaden wires are said to transmit nothing. The wire must not be bent at a sharp angle, nor should it be rough at any point, for in these cases the internal reflections along its boundary can not be propagated.

N_1 RAYS.

Some very recent experiments of M. Blondlot led him to think that, whereas the N rays augument the luminosity of certain sources of light, there is another kind of rays associated with them which diminishes instead of augments the luminosity, and he has investigated these rays among those emitted by a Nernst lamp. These so-called N_1 rays he finds to be reflected and refracted similarly to the N rays, but to lie alternately with them in wave length, so that, for example, he states that a group of N_1 rays exists of wave length $.003\mu$, a group of N rays at 0.0048μ, another group of N_1 rays at 0.0056μ, N rays at 0.0067μ, and N_1 rays at 0.0074μ. All of these new groups, both N and N_1, are of smaller wave length than those included in the table already given.

Certain sources appear to emit exclusively, or at least principally, the N_1 rays, such as copper, silver, and platinum. The N_1 rays may be stored up, he states, like the N rays.

CONCLUSION.

To sum up these newly reported discoveries and experiments, it appears that several other men of scientific standing and attainments have repeated and verified M. Blondlot's discoveries of the N and N_1 rays and those of M. Charpentier on the rays emitted by living bodies. The observations appear, however, to be difficult, and many able observers who have endeavored to repeat the experiments have not been able to verify even the existence of such radiations, to say nothing of making measurements of their wave length by the diffraction grating. It has been stated in criticism that augmentation of brightness in phosphorescent substances may be the result of several causes,

perhaps not sufficiently excluded from M. Blondlot's experiments. As we have seen, however, M. Blondlot does not depend wholly on phosphorescent screens to observe his rays, and he remarks the difference in sensitiveness of eyes to minute changes of the intensity of light, so that this negative evidence is not a disproof of the existence of the rays in question. On the other hand, the positive photographic evidence afforded in the illustrations given by M. Blondlot, which does not at all depend on phosphorescence, but only on the brightness of the little sparking device, seems to outweigh indications depending merely on sight alone.

In connection with M. Charpentier's physiological rays, it may be recalled by the reader that a half century ago there was great interest aroused, both in scientific and popular circles, by the accounts of the so-called "odic force" of Reichenbach. This was said to be manifested as a luminous aureole which appeared to some observers to surround certain persons. For some time there was a controversy between those who claimed they could see it and those who certainly could not see it, but at length the discussion disappeared from the journals, and the general impression has been that no such thing really existed.

Some persons have thought that these new discoveries of M. Charpentier and others may in a certain sense revive the old idea of such an aureole thrown out by living people, but the methods of observing the new rays are evidently wholly different. The physiological rays now being discussed can not be seen by the naked eye, nor do they affect the photographic plate or any other of the ordinary means of observing light, and they are only to be distinguished indirectly by the augmentation of brightness which they produce in feebly luminous objects. Accordingly, however interesting it may be if we know that the living body actually is surrounded by special radiations which it emits in addition to those rays of great wave length which we have long known are emitted by every body, living or dead, above the temperature of absolute zero, still so long as our eyes can not see them they can hardly be supposed to belong in the category of the aureole of Reichenbach. It is to be hoped that they will not, like this asserted aureole, fall into scientific oblivion.

MODERN VIEWS ON MATTER.[a]

By Sir Oliver Lodge, Hon. D. Sc., F. R. S.

The nature of matter has been regarded by philosophers from many points of view, but it is not from any philosophic standpoint that I presume in this university to ask you to consider the subject under my guidance. It is because new views as to the structure and properties of what used to be called the ultimate atom are now being born, and because these views, whether they succeed in ultimately establishing themselves in every detail or not, are of surpassing interest, that I have chosen this very recently deciphered chapter of science as the subject-matter for the lecture—the Romanes lecture—to be given this year in remembrance of a man whom I knew as a friend, and whose mind, if he had been alive to-day, would have been widely open to these most modern developments of physical science. Nor would the admittedly speculative character of some of the hypotheses now being thrown out have deterred him from hearing about them with the keenest interest.

If I may venture to say so, it is the more philosophical side of physics which has always seemed to me most suitable for study in this university; and although I disclaim any competence for philosophic treatment in the technical sense, yet I doubt not that the new views, in so far as they turn out to be true views, will have a bearing on the theory of matter in all future writings on philosophy, besides exercising a profound effect on the pure sciences of physics and chemistry, and perhaps having some influence on certain aspects of biology also.

In admitting that I am going to promulgate a speculative hypothesis that is, a hypothesis for which there is evidence but not yet conclusive evidence—I must not lead you to suppose that the whole of what I have to say is of this character. On the contrary, much of it is certain; that is to say, is accepted by a consensus of opinion to-day among those who by reason of study are competent to judge. I will endeavor carefully to discriminate between what is in this sense certain and what must still be regarded as doubtful and needing further support.

[a] The Romanes Lecture, delivered in the Sheldonian Theater, Oxford, June 12, 1903. Reprinted by permission of the author. Published by the Clarendon Press, Oxford, England, 1903.

To treat the subject properly, to give all the evidence as well as the results, would need a volume, or a course of lectures; and in order to be brief I must frequently be dogmatic, but I shall only intend to be so in those places where I feel sure that the physicists present (whom here I salute) will agree with me. When I have a dogma of this kind to propound I shall call it a thesis. The more speculative opinions I shall plainly denominate hypotheses.

1. My first thesis is that an electric charge possesses the most fundamental and characteristic property of matter, viz, mass or inertia; so that if anyone were to speak of a milligram or an ounce or a ton of electricity, though he would certainly be speaking inconveniently, he might not necessarily be speaking erroneously. At the same time it would be well to mistrust anyone who employed such a phrase, except in speaking to experts. He would most likely be talking nonsense; but if he talks nonsense to experts, his blood is on his own head.

In order to have any appreciable mass, however, an electric charge must either be extremely great or must be extremely concentrated, and unless it is to be utterly masked by the matter with which it is associated it must be the latter; that is to say, it must exist on bodies of far less than ultra-microscopic size. The mass or inertia of a charge depends upon two factors—the quantity of electricity in it, and its potential—and by concentrating a given charge onto a sufficiently small sphere the latter factor can be raised theoretically to any value we please, and thus any required inertia can be obtained, unless a stage is reached at which it becomes physically impossible to concentrate it any more.

2. The next thesis is a very simple and familiar one, and dates virtually from the time of Faraday, though the conception has gradually gained in clearness and solidity. It is that every atom of matter can have associated with it a certain definite quantity of electricity called the ionic charge; that some atoms can have double this quantity, some treble, and so on, but that no atom or any piece of matter can have a fraction of this quantity; which therefore appears to be an ultimate unit, a sort of "atom," of electricity. The ratio of the charge to the weight of a material atom is measured with accuracy in electrolysis, in accordance with what are called Faraday's laws; and in so far as the mass of the atom itself is otherwise approximately known the quantity of electricity which can be associated with it is known with a similar degree of approximate accuracy.

3. Now, mathematical data were given by J. J. Thomson in 1881 which enable us to say that if the charge of electricity usually associated with a single monad atom of matter were concentrated on to a spherical nucleus one hundred-thousandth of an atom's dimension in diameter, it would thereby possess a mass about one-thousandth of that of the lightest atom known, viz, the hydrogen atom.

Such a hypothetical concentrated unit of electricity it has become customary to call an "electron," a name invented by Dr. Johnstone Stoney to designate the so-to-speak "atom" or smallest known unit of electric charge. Every electric charge is to be thought of as due to the possession of a number of electrons, but a fraction of an electron is at present considered impossible, meaning that no indication of any further subdivision has ever loomed even indistinctly above the horizon of practical or theoretical possibility.

The electrification of an atom of matter consists in attaching such an electron to it or in detaching one from it. An atom of matter possessing an electron in excess is called an "ion;" and there is reason to know that, considered as a charged body, its charge is that which we have been historically accustomed to designate "negative:" whereas an atom of matter with one electron in defect is that which has historically been called a "positive" ion.

This inversion in the natural use of the names positive and negative is inconvenient but accidental and not really serious; it dates from the time of Benjamin Franklin.

These ions or traveling particles of matter have been long known. A liquid or a gas conducts because of the locomotion of its charged particles. The particles travel in an electric field because of their attached charges, all the positive going one way, and all the negative the other way; and each kind of matter possesses an intrinsic or characteristic ionic velocity, when urged by a given field through a given solution. The charges may be likened to horses or other propelling agency, and the atom to the vehicle or heavy body which is dragged along. The speed of travel through liquids is very slow, but through gases is considerably quicker, partly because there is less resistance, and partly because it is easier to maintain a steep gradient of potential in a medium where the ions are not too numerous.

The act of production of such ions is styled "ionization," and the process has been employed to explain very many facts in both physics and chemistry.

As an example, Röntgen rays passing through air ionize it and so render it conducting for a time; wherefore they are able readily to discharge electrified bodies in this secondary way.

It may be convenient here to emphasize the dimensions of an electron as above specified, for the arguments in favor of that size are very strong, though not absolutely conclusive; we are sure that their mass is of the order one thousandth of the atomic mass of hydrogen, and we are sure that if they are purely and solely electrical their size must be one hundred-thousandth of the linear dimensions of an atom; a size with which their penetrating power and other behavior is quite consistent. Assuming this estimate to be true, it is noteworthy how very small these electrical particles are, compared with the atom of matter

to which they are attached. If an electron is represented by a sphere an inch in diameter, the diameter of an atom of matter on the same scale is a mile and a half. Or if an atom of matter is represented by the size of this theater, an electron is represented on the same scale by a printer's full stop. It is well to bear this extreme smallness in mind in what follows.

An atom is not a large thing, but if it is composed of electrons, the spaces between them are enormous compared with their size—as great relatively as are the spaces between the planets in the solar system.

4. My next thesis is that these electrons or minute-charged corpuscles can exist separately, for they can be detached from their atoms of matter at an electrode, not only in electrolytic liquids but also in gases, and when thus released from their thousandfold more massive atom, they fly away from the negative electrode with prodigious speed, because they are acted on by the same electrical propelling force as before, but now have hardly anything to move.

These isolated flying particles travel a long distance in rarefied gas, and are known as cathode rays. They were studied by Hittorf, Crookes, Lenard and others, both inside and outside vacuum tubes, and they are now known to be flung off spontaneously from many substances. When stopped suddenly by a massive obstacle, they give rise to the X radiation discovered by Röntgen. At first these cathode rays were thought to be atoms of matter, though their extraordinary penetrating power rendered such a hypothesis difficult of belief, and caused Crookes to speak of them as matter in a fourth state. They are, however, certainly energetic bodies, being able to propel light windmills, to heat platinum to redness, and to charge an electroscope; they are also able to penetrate thin sheets of metal and to affect photographic plates or phosphorescent substances on the other side. They are not so penetrating, however, as are some of the Röntgen rays.

The final definite establishment of the fact that these flying particles are not atoms of matter, but are bits chipped off the atoms, fractions of an atom, as it were, the same identical kind of bits being chipped off every kind of chemical atom, their mass always about one-thousandth of that of a hydrogen atom, and moving under favorable circumstances with something not much less than the speed of light, is due to the researches of Prof. J. J. Thomson and his coadjutors in the Cavendish Laboratory, Cambridge, and represents a long series of measurements devised and executed with consummate skill.

I have no time to go into detail concerning these important and elaborate and most interesting investigations. Suffice it to say that portions of them are due to your own Wykeham professor of physics, Professor Townsend, working in conjunction and collaboration with others, under the leadership of Prof. J. J. Thomson; and that this whole series of Cavendish Laboratory researches may be said to con-

stitute the high-water mark of the world's experimental physics during the beginning of this century.

5. I must not dwell upon the properties and powers of electrons, nor upon the experimental means by which these measurements were made, for it is far too large a subject. I must exhibit a few diagrams, and briefly summarize a few main facts.

Electrons have been shown to be shot off from any negatively charged body, especially from negatively electrified metals, when exposed to ultra-violet light.

When shot into a mass of air they ionize that air for a time and render it electrolytically conducting; also, of course, they can discharge positively electrified bodies themselves, and can thus be most readily detected in small numbers.

Electrons in orbital motion have been shown to constitute the mechanism by which atoms are able to radiate light; and a great mass of semiastronomical facts concerning these orbits and their perturbations have been obtained by immersing the source of light in a strong magnetic field and observing the minute but very definite changes of spectra thereby produced, a branch of science with which the names of H. A. Lorentz, of Leyden, and Zeeman, of Amsterdam, will be inseparably associated.

In all these and other ways the electron has become a familiar object. It constitutes the ionic charge of matter. Multiples of it, but no fractions, are possible. Its mass, its charge, and its speed have been frequently measured by different processes, and always with consistent results. It is the most definite and fundamental and simple unit which we know of in nature.

It has thus displaced the so-called atom of matter from its fundamental place of indivisibility. The atom of matter has been shown capable of losing an electron, of having at least one chipped off it. The electron has been shown to possess in kind, though not in degree, the fundamental properties of the original atom of which it had formed a part; and it becomes a reasonable hypothesis to surmise that the whole of the atom may be built up of positive and negative electrons interleaved together, and of nothing else; an active or charged ion having one electron in excess or defect, but the neutral atom having an exact number of pairs. The oppositely charged electrons are to be thought of on this hypothesis as flying about inside the atom, as a few thousand specks like full stops might fly about inside this hall, forming a kind of cosmic system under their strong mutual forces, and occupying the otherwise empty region of space which we call the atom—occupying it in the same sense that a few scattered but armed soldiers can occupy a territory—occupying it by forceful activity, not by bodily bulk.

6. The hypothetical part of the statement about the size of an electron is the following. Whereas both the mass and the charge of an electron are known, it is not yet quite certain that the mass is wholly due to the charge. It is possible, but to me very unlikely, that the electron, as we know it, contains a material nucleus in addition to its charge, so in that case it need not be so concentrated, because a portion of its mass would be otherwise accounted for.

I say "accounted for," but it would be equally true to say "unaccounted for." The mass which is explicable electrically is to a considerable extent understood, but the mass which is merely material (whatever that may mean) is not understood at all. We know more about electricity than about matter, and the way in which electrical inertia is accounted for electromagnetically and localized in the ether immediately surrounding the nucleus of charge is comparatively clear and distinct.

There may possibly be two different kinds of inertia which exactly simulate each other, one electrical and the other material, and those who hold this as a reasonable possibility are careful to speak of electrons as "corpuscles," meaning charged particles of matter of extremely small size, much smaller than an atom, consisting of a definite electric charge and an unknown material nucleus, which nucleus, as they recognize, but have not yet finally proved, may quite possibly be zero.

The chief defect in the electrical theory of matter at present is that the positive electron, if it exists, has never yet been isolated from the rest of an atom of matter. It has never been found detached from a mass less than the hydrogen atom; whereas the negative electron is constantly and freely encountered flying about alone, its mass being little more than the thousandth part of an atom of hydrogen.

Until a positive electron can be similarly isolated, the hypothesis that an atom is really composed solely of electricity—that is to say, of equal quantities of positive and negative electricity associated together in a certain grouping of little bodies, each of which is nothing more than a concentrated charge of electricity of known amount—must remain a hypothesis.

7. It is a fascinating guess that the electrons constitute the fundamental substratum of which all matter is composed; that a grouping of, say, 700 electrons, 350 positive and 350 negative, interleaved or interlocked in a state of violent motion so as to produce a stable configuration under the influence of their centrifugal inertia and their electric forces, constitutes an atom of hydrogen; that sixteen times as many, in another stable grouping, constitute an atom of oxygen; that some 16,000 of them go to form an atom of sodium, about 100,000 an atom of barium, and 160,000 an atom of radium.

On this view all the elements would be regarded as different groupings of one fundamental constituent. Of all the groupings possible, doubtless most are so unstable as never to be formed; but some are stable, or at least relatively stable, and these stabler groupings constitute the chemical elements that we know. The fundamental ingredient of which, on this view, the whole of matter is made up, is nothing more or less than electricity, in the form of an aggregate of an equal number of positive and negative electric charges.

This, when established, will be a unification of matter such as has through all the ages been sought; it goes further than had been hoped, for the substratum is not an unknown and hypothetical protyle, but the familiar electric charge. Nevertheless, of course, it is no ultimate explanation. The questions remain, What, then, is an electric charge? What is the internal structure and constitution of an electron? Wherein lies the difference between positive and negative electricity? and What is their relation to the ether of space? Definite questions these, and doubtless some day answerable; indeed, powerful methods of attack on this position have been already contrived by Dr. J. Larmor and others; but they are questions of a higher order of difficulty than those which occupy us to-day, and it must remain for a future Romanes lecturer to report progress in these directions, whenever adequate progress has, in fact, been made.

8. That is the end of the first half of my lecture; and six months ago that, somewhat expanded, might have been the whole of it, because the next portion would have seemed too fanciful; but discoveries have been made, chiefly in France and in Canada—some of the most striking of them within the present year—which remove the treatment of the next part of my subject from the realm of fancy to the region of probability, and justify my proceeding further with some of the theoretical consequences deducible from an electric theory of matter.

I referred above briefly to the origin of radiation, saying that by the method of applying a powerful magnet to a source of light, and examining the minute perturbations in the lines of the spectrum thus produced, it had been proved that the real source of radiation was an electric charge in rapid orbital motion; and I now go on to say that by careful measurement of the amount of perturbation it has been definitely proved that it is our friends the negative electrons, with a mass about one thousandth of the smallest known atom of matter, that are responsible for the excitation of ether waves or the production of light. Larmor and others have, indeed, shown mathematically that whenever an electric charge is subject to acceleration, an emission of some amount of radiation is inevitable, by reason of the interaction of its electric and magnetic fields; and it is probable that there is no other source of light or radiation possible except this change in the

motion of electrons. It is known, for instance, that the violent acceleration or retardation of electrons when they encounter an obstacle is responsible for the excitation of Röntgen rays. All light and all the Hertz waves or pulses employed in wireless telegraphy are due to electric acceleration, and the greater the rate of change of velocity the more violent is the radiation emitted.

The charge may oscillate, as in a Hertz vibrator, or it may revolve, as in a source of ordinary light, such as a sodium flame. In order to emit perceptible radiation by revolving, it must revolve with extreme speed in a very small orbit, so that its rate of curvature or centripetal acceleration may be considerable; for it is on the square of the value of the average acceleration that the energy of radiation depends.

9. All this is of the nature of a definite and certain thesis, but now we are going to apply it to our hypothesis that the atom of matter is either wholly or partially composed of electrons in a state of vigorous motion among themselves. Such revolving or vibrating electrons are subject to acceleration, either radial or tangential, and must therefore to a greater or less extent necessarily emit radiation; it becomes natural to inquire whence comes the energy that is radiated away.

Now, in ordinary familiar cases it is the irregular agitation of molecules which we call "heat" that is being radiated away; and in that case the result is a mere cooling, or diminution of the molecular agitation, which can readily be made up by receipt of similar energy from the inclosures or from surrounding bodies; or, if not made up, it can produce the ordinary well-known effects of "cold." But to the motion of the internal parts of an atom the ideas of heat and temperature do not apply. The atom, if it lose energy, must lose what is to it an essential ingredient, and hence this inevitable radiating power of the constituents of an atom seemed to constitute a difficulty, for it suggested that an atom of matter was not really a permanent and eternal thing, but that it contained within itself the seeds of its own decay and ultimate dissipation into the separate electrons of which it was composed. The process might indeed be exceedingly slow, the radiation loss might be almost imperceptible, but, in so far as an atom is composed of revolving electrons, it is inevitable that radiation of energy must go on from it, and that this must in the long run have some perceptible degenerative result.

10. That result has quite recently, I believe, been experimentally discovered, and is a part of the phenomenon known as "radio-activity."

So now we come to the most remarkable and probably the most interesting step of all.

The phenomenon of spontaneous radio-activity, discovered first by Becquerel in uranium and thorium, and greatly extended by the brilliant chemical researches of M. and Mme. Curie which resulted in the discovery of radium, was at first supposed to consist in the emission of

a sort of X rays or ether pulses; and was subsequently assumed to consist chiefly in the bodily emission of electrons; which were shot off from the radio-active substance as they are from a negative electrode in a vacuum tube, or as they are in air when ultra-violet light falls upon clean negatively charged surfaces.

As a matter of fact, both these modes of radiation—the wave form and the corpuscular form—are emitted by radio-active bodies, but they turn out to be of subordinate importance, and must be regarded as secondary or subsidiary results of the main phenomenon.

The main fact of radio-activity has been shown by Professor Rutherford, of Montreal, in a paper published in the month of February this very year, to consist in the flinging away with great violence of actual atoms of matter—atoms electrified indeed, but not negatively like electrons, and not small or penetrating like them, but full-sized atoms, such as are easily stopped by a thin sheet of metal, or even by a sheet of paper—atoms which are positively charged and possessed of a remarkable amount of energy, ionizing the air which they bombard to an extraordinary extent, and likewise generating quite a perceptible amount of heat wherever they strike; producing indeed a flash when they strike a suitable target, as Crookes has shown, quite like the impact of a cannon ball on an armor plate. Their speed, indeed, far exceeds that of any cannon ball that ever existed, being as much faster than a cannon ball as that is faster than a snail's crawl; a hundred times faster than the fastest flying star, these atomic projectiles constitute the fastest moving matter known. This furious bombardment from a radio-active substance continues without intermission and apparently without sign of diminution or cessation. There is every reason to believe that a minute scrap of radium, scarcely perceptible to the eye, may go on emitting these energetic projectiles for hundreds of years.

11. At first sight the fact that it is merely atoms of matter which are being flung off by most radio-active substances, and that ethereal and other effects are subsidiary to this emission of substance, seems to lessen the interest attaching to the phenomenon, reducing it to something of merely chemical importance and suggesting a resemblance to scent or other volatilization from solid bodies. But Professor Rutherford, with great skill, succeeded in determining approximately the atomic weight of the utterly imperceptible amount of substance thrown off, as well as its speed, and found that it was not by any means the radio-active substance itself which was evaporating, but something quite different.

Plainly, if an elementary form of matter is found to be throwing off another substance, it becomes imperative to inquire what that substance is and what it is that is left behind. Now, the atomic weight of radium, or of thorium or uranium, or of any known strongly radio-

active substance, is very high, in each case over two hundred times the atomic weight of hydrogen, whereas the atomic weight of the substance flung off appears to be more nearly of the order one or two; in other words, the substance thrown off is more likely to be either hydrogen or helium than it is likely to be radium. It is just possible that the inert chemical elements are by-products of radio-activity.

Now, clearly here is a fact, if fact it be, of prodigious importance. Undoubtedly the measurements require confirmation, but for myself I see no reason to doubt them, at least as regards their order of magnitude. The atomic weight of radium being, say, 225, and that of the projected portion being, say, 2, the residue must represent by its atomic weight the difference between the heavy atom of the original substance and that of the light atom or atoms which have been flung away, unless indeed it be assumed, as it will almost certainly be assumed by some skeptical chemists, those who derided argon and other chemical discoveries when made in a physical manner, that the substance flung away is some foreign ingredient or impurity—a hypothesis, I venture to say, already strongly against the weight of available evidence.

The substance left behind in the pores of the radio-active substance has been examined even more completely than the projected portion; it is volatile, it slowly diffuses away, and it behaves like a gas. It can be stored in gas holders when mixed with air, for in amount it is quite imperceptible to all ordinary tests; and yet it can be passed through pipes and otherwise dealt with. It condenses not far above the temperature of liquid air, and it is itself radio-active, but in such a way that its power decays rapidly with time. Its radio-activity seems to consist likewise in throwing away part of itself and leaving yet another residue, likewise radio-active; and one of the residues so left seems ultimately to pitch away electrons simply instead of atoms of matter. It is not to be supposed that thorium and radium and uranium all behave alike in details. The emanation of one may lose its activity rapidly, and give rise to another substance which retains its power for some time; the emanation of another element may last some time and generate a substance whose activity rapidly decays, but into these details it is not now the place to go.

12. Assuming the truth of this strange string of laboratory facts, we appear to be face to face with a phenomenon quite new in the history of the world. No one has hitherto observed the transition from one form of matter to another, though throughout the Middle Ages such a transmutation was looked for. The transmutation of elements has been suspected in modern times on evidence vaguely deducible by skilled observers from the spectroscopic details of solar and stellar appearances. The evolution of matter has likewise been suspected by a few chemists of genius. It was perceived, on the strength of Mendelejeff's law, that the elements form a kind of family or related series,

and it was surmised that possibly the barriers between one species and the next were not absolutely infrangible, but that temporary transitional forms might occur. All this was speculation; but here in radioactive matter the process appears to be going on before our eyes. Professor Rutherford and Mr. Soddy, who in Canada during the present year have worked hard and admirably at the subject, have adduced facts which point clearly in this direction; and they initially describe what appear to be the first links of a chain of substances, all produced in hopelessly minute quantities reckoned by ordinary tests, but which yet by electrical means can easily be detected, and their boiling points and other properties investigated. Moreover, the investigators of these strange substances are able to dissolve and precipitate, and perform ordinary chemical operations on, these utterly imponderable and hopelessly minute deposits of radio-active substances, because of the powerful means of detection which their ionizing power puts into our hands—even a few stray atoms being able by their ionizing power to discharge an electroscope appreciably.

13. Thus, then, it would appear that our theoretical conclusion concerning the inevitable radiation and loss of energy from electrically constituted atoms of matter, a loss which must involve them in necessary change and dissolution, meets with quite unexpectedly rapid confirmation, and it is for that reason that I feel willing to accept tentatively and as a working hypothesis this explanation of radio-activity. It represents a fact previously wanted on theoretical grounds. For how is radio-activity to be explained? It looks as if the massive and extremely complex atoms of a radio-active substance were liable to get into an unstable condition, probably reaching this condition whenever any part of it attempts or is urged to move with the velocity of light. I have shown elsewhere[a] that the mere fact of radiation will act as a resisting medium and increase the speed of the particles automatically, on the same principle that a comet would be accelerated if it met with resistance, since the inverse-square law applies to electrical central forces. Electrical mass is not strictly constant; it is a function of speed, but in such a way that it is practically constant until the velocity of light is very nearly attained. That is a critical velocity, which apparently can not be surpassed. When this critical speed is reached any electrified body becomes suddenly of infinite mass, and something is bound to happen. What that something is, it is not easy theoretically to say, but the partial or incipient disintegration or dissociation of the atom and the flying away of a portion with a speed comparable to that of light is no unlikely result.

Out of the whole multitude of atoms, even of the atoms of a conspicuously radio-active substance, it is probable that only a very few get into this unstable or critical condition at any one time; perhaps not

[a] See Nature, June 11, 1903.

more than one in a million million. Nevertheless, just as occasional though rare encounters take place in the heavens, followed by the blaze of a new and temporary star, so, though probably not by the same mechanism, here and there a few out of the billions of atoms in any perceptible speck of radium arrive in due time at the unstable condition and break down into something else, with energetic radioactivity during the sudden collapsing process, emitting in the process of collapse not only the main projected substance, but likewise also a few electrons and those X rays which always accompany a sudden electric jerk or recoil. And the X rays so emitted are of the most penetrating kind known, being able to pass through an inch of solid iron in perceptible quantity.

14. The hypothesis concerning radio-activity which is now in the field, then, is that a very small number—an almost infinitesimal proportion—of the atoms are constantly breaking up, throwing away a small portion, say 1 per cent, of themselves with immense violence at about one-tenth of the speed of light; the remainder constitute a slightly different substance, which, however, is still extremely unstable, and therefore radio-active, going through its stages with much greater rapidity than the radium itself, because practically the whole of it is in the unstable condition, and so giving rise to fresh and fresh products of its own decay, till a comparatively stable state is reached, or till the process passes beyond our means of detection.

Roughly, the process may be likened in some respects to the condensation or contraction of a nebula. The particles constituting a whirling nebula fall together until the centrifugal force of the peripheral portions exceeds the gravitative pull of the central mass, and then they are shrunk off and left behind, afterwards agglomerating into a planet, while the residue goes on shrinking and evolving fresh bodies and generating heat. A nebula is not hot, but it has an immense store of potential energy, some of which it can turn into heat, and so form a hot central nucleus or sun. A radium atom is not hot, but it, too, has a great store of potential energy, immense in proportion to its mass, for it is controlled by electrical, not by gravitational forces; and just as the falling together of the solar material generates heat, so that a shrinkage of a few yards per century can account for all its tremendous emission, so it has been calculated that the collapsing of the electrical constituents of a radium atom, by so little as 1 per cent of their distance apart, can supply the whole of the energy of the observed radiation—large though that is—for something like thirty thousand years.

15. It does not follow that the life of a piece of radium is as great as that; the data are uncertain at present, but there is absolutely no ground for the popular and gratuitous surmise that it emits energy without loss or waste of any kind, and that it is competent to go on forever. The idea, at one time irresponsibly mooted, that it contra-

dicted the principle of the conservation of energy, and was troubling physicists with the idea that they must overhaul their theories—a thing which they ought always to be delighted to do on good evidence—this idea was a gratuitous absurdity and never had the slightest foundation; but the notion that radium was perhaps able to draw upon some unknown source or store of energy, without itself suffering loss, was a possibility which has not yet wholly disappeared from some minds. Sir W. Crookes, for instance, suggested that it might somehow utilize the most quickly moving atoms of air, after the fashion of a Maxwell demon—a possibility that should always be borne in mind as a conceivable explanation of the power of some living organisms. It is much more reasonable to suppose, however, that radium and the other like substances are drawing upon their own stores of internal atomic energy, and thereby gradually disintegrating and falling into other, and ultimately into more stable, forms of matter.

Not that it is to be supposed that even these are finally and absolutely stable; these, too, are subject to radiation loss, and so must be liable to decay, but at a vastly slower rate, perhaps not more than a few hundred atoms changing and diffusing away each second—a process utterly imperceptible to the most delicate weighing until after the lapse of millions of years, so that for all practical purposes, and for times such as are dealt with in cosmic history, they are permanent, even as the solar system and stellar aggregates appear to us to be permanent. Yet we know that all these systems are in reality transitory, as terrestrial structures like the pyramids or as the mountains and the continents themselves are transitory; of all these things it may be said that in any given form they have their day and cease to be. But whereas geological and astronomical configurations pass through their phases in a time to be reckoned in millions of years, the active life of a solar system covering perhaps no very long period, it is probable that the changes we have begun to suspect in the foundation stones of the universe, the more stable elemental atoms themselves, must require a period to be expressed only by millions of millions of centuries. For in such a time as this, at the rate of a hundred atoms per second, a bare kilogram—a couple of pounds only—of matter, even of heavy matter, would have drifted away, not so much indeed—a couple of ounces more likely. And yet this period is a million times the estimated age of the earth.

16. If we allow ourselves to speculate on the strength of the slender experimental evidence as yet forthcoming, instead of waiting, as to be wise we must wait, for confirmation and thorough examination of the facts, we should say that the whole of existing matter appears liable to processes of change, and in that sense to be a transient phenomenon.

Somehow, we might conjecture, by some means at present unknown, it takes its rise: electrons of opposite sign crystallizing or falling together, perhaps at first into a manifestly unstable form; these forms

then pass on from one into another, going through a series of transitional states, and abiding for a long time in those configurations which are most stable; giving a process of evolution inconceivably slow in its later stages, comparatively rapid in its early ones, and yet not so rapid, even in a substance like radium, but that its life as such may be reckoned by thousands of years.

If such a transitory existence is ever established for the forms of matter as we know them, it by no means follows that the process goes on in one direction only, or that the total amount of matter in the universe is subject to diminution. There may be regeneration as well as degeneration.

The total amount of radio-activity in a substance is singularly constant. If the radio-active portion is removed, a fresh supply makes its appearance at a measured rate, that rate being expressible by a decreasing geometrical progression, and being precisely equal to the rate at which the power of the removed portion decays.

Whether the total amount of matter in the universe is constant likewise, as much disappearing at one end by resolution into electrons as is formed at the other end by their aggregating together, is at present quite unknown; and, indeed, it is clear that we have now become far immersed in the region of speculation. Nevertheless, it is speculation not of an illegitimate character, for it is very consistent with all that we know about the rest of the material universe.

Astronomy tells us that the cosmic scheme, though it looks permanent, is subject to constant flux. In the sky we see solar systems and suns in process of formation by aggregation out of nebulæ; we see them rise in brilliancy, maintaining a number of planets in health and activity for a time, and then slowly become subject to decay and death. What happens after that is not certainly known. It may be that by collision a nebula may be reconstituted and the process started again; though so long as there is only a force of one sign at work (gravitation only) it would seem that ultimately the regenerative process must come to an end. The repellent force exerted by light upon small particles, however, must not be forgotten; it can overcome gravitation when it acts on small enough bodies; and there are other possibilities. Among the parts of an atom certainly the forces are conspicuously not of one sign. Inside an atom there exist both attractive and repulsive forces. The resolution of an atom into its electron constituents, and the aggregation of these constituents into fresh atoms, are both perfectly thinkable. All we have to do is to ascertain by careful and patient investigation what really happens; and my experience has led me to feel sure of this that whatever hypotheses and speculations we may frame, we can not exceed the reality in genuine wonder; and I believe that the simplicity and beauty of the truth concerning even the material universe, when we know it, will be such as to elicit feelings of reverent awe and adoration.

MODERN VIEWS ON MATTER: THE REALIZATION OF A DREAM.[a]

By Sir William Crookes, F. R. S., etc.

For nearly a century men who devote themselves to science have been dreaming of atoms, molecules, ultramundane particles, and speculating as to the origin of matter; and now to-day they have got so far as to admit the possibility of resolving the chemical elements into simpler forms of matter, or even of refining them altogether away into ethereal vibrations of electrical energy.

This dream has been essentially a British dream, and we have become speculative and imaginative to an audacious extent, almost belying our character of a purely practical nation. The notion of impenetrable mysteries has been dismissed. A mystery is a thing to be solved—"and man alone can master the impossible." There has been a vivid new start. Our physicists have remodeled their views as to the constitution of matter and as to the complexity if not the actual decomposability of the chemical elements. To show how far we have been propelled on the strange new road, how dazzling are the wonders that waylay the researcher, we have but to recall—matter in a fourth state, the genesis of the elements, the dissociation of the chemical elements, the existence of bodies smaller than atoms, the atomic nature of electricity, the perception of electrons, not to mention other dawning marvels far removed from the lines of thought usually associated with English chemistry.

The earliest definite suggestion in the last century of the possible compound nature of the elements occurs in a lecture delivered in 1809[b] by Sir Humphry Davy at the Royal Institution. In that memorable lecture he speculated on the existence of some substance common to all the metals, and he averred that "If such generalizations should be supported by facts, a new, a simple, and a grand philosophy would be the result. From the combination of different quantities of two or

[a] An address delivered before the Congress of Applied Chemistry at Berlin, June 5, 1903. Reprinted from author's pamphlet copy, London, 1903.

[b] Works of Sir Humphry Davy, Vol. VIII, p. 325.

three species of ponderable matter we might conceive all the diversity of material substances to owe their constitution."

Again, in 1811, he said:[a]

It will be useless to speculate upon the consequences of such an advancement in chemistry as that of the decomposition and composition of the metals. * * * It is the duty of a chemist to be bold in pursuit. He must not consider things as impracticable merely because they have not yet been effected. He must not regard them as unreasonable because they do not coincide with popular opinion. He must recollect how contrary knowledge sometimes is to what appears to be experience. * * * To inquire whether the metals be capable of being decomposed and composed is a grand object of true philosophy.

Davy first used the term "radiant matter" about 1809, but chiefly in connection with what is now called "radiation." He also used the term in another sense, and the following passage[b] in its clear forecast is prophetic of the modern electron:

If particles of gases were made to move in free space with an almost infinitely great velocity—i. e., to become radiant matter—they might produce the different species of rays, so distinguished by their peculiar effects.

In his lectures at the Royal Institution, in 1816, "On the general properties of matter," another prescient chemist, Faraday, used similar terms when he said:

If we conceive a change as far beyond vaporization as that is above fluidity, and then take into account also the proportional increased extent of alteration as the changes rise, we shall, perhaps, if we can form any conception at all, not fall far short of radiant matter; and as in the last conversion many qualities were lost, so here also many more would disappear.

Again, in one of his early lectures he strikes a forward note:

At present we begin to feel impatient and to wish for a new state of chemical elements. To decompose the metals, to re-form them, and to realize the once absurd notion of transmutation are the problems now given to the chemist for solution.

But Faraday was always remarkable for the boldness and originality with which he regarded generally accepted theories. In 1844 he said:

The view that physical chemistry necessarily takes of atoms is now very large and complicated; first many elementary atoms—next compound and complicated atoms. System within system, like the starry heavens, may be right—but may be all wrong.

A year later Faraday startled the world by a discovery to which he gave the title "On the magnetization of light and the illumination of the magnetic lines of force." For fifty years this title was misunderstood and was attributed to enthusiasm or confused ideas. But to-day we begin to see the full significance of the Faraday dream.

It was not till 1896 that Zeeman showed a spectrum line could be acted on by a magnetic field. A spectrum line is caused by motion of the electron acting on the ether, which can only move and be moved

[a] Loc. cit., Vol. VIII, p. 330.
[b] Loc. cit., Vol. VIII, p. 349.

by the electron. A magnetic field resolves this motion into other component motions—some slower, others quicker—and thus causes a single line to split into others of greater and less refrangibility than the parent line.

In 1879, in a lecture I delivered before the British Association[a] at Sheffield, it fell to my lot to revive "radiant matter." I advanced the theory that in the phenomena of the vacuum tube at high exhaustions the particles constituting the cathode stream are not solid, nor liquid, nor gaseous, do not consist of atoms propelled through the tube and causing luminous, mechanic, or electric phenomena where they strike, "but that they consist of something much smaller than the atom—fragments of matter, ultra-atomic corpuscles, minute things, very much smaller, very much lighter than atoms—things which appear to be the foundation stones of which atoms are composed."[b]

I further demonstrated that the physical properties of radiant matter are common to all matter at this low density—"Whether the gas originally under experiment be hydrogen, carbon dioxide, or atmospheric air, the phenomena of phosphorescence, shadows, magnetic deflection, etc., are identical." Here are my words, written nearly a quarter of a century ago: "We have actually touched the border land where matter and force seem to merge into one another[c]—the shadowy realm between the known and unknown. I venture to think that the greatest scientific problems of the future will find their solution in this border land, and even beyond; here, it seems to me, lie ultimate realities, subtle, far-reaching, wonderful."

It was not till 1881 that J. J. Thomson established the basis of the electro-dynamic theory. In a very remarkable memoir in the Philosophical Magazine he explained the phosphorescence of glass under the influence of the cathode stream by the nearly abrupt changes in the magnetic field arising from the sudden stoppage of the cathode particles.

The now generally accepted view that our chemical elements have been formed from one primordial substance was advocated in 1888 by me when president of the Chemical Society,[d] in connection with a theory of the genesis of the elements. I spoke of "an infinite number of immeasurably small ultimate—or, rather, ultimatissimate—particles gradually accreting out of the formless mist, and moving with inconceivable velocity in all directions."

Pondering on some of the properties of the rare elements, I strove to show that the elementary atoms themselves might not be the same

[a] British Association Reports, Sheffield meeting, 1879. Chemical News, Vol. XL, p. 91. Phil. Trans. Roy. Soc., 1879, Pt. I, p. 585. Proc. Roy. Soc., 1880, No. 205, p. 469.

[b] Sir O. Lodge, Nature, Vol. LXVII, p. 451.

[c] "Matter is but a mode of motion" (Proc. Roy. Soc., No. 205, p. 472).

[d] President's address to Chem. Soc., March 28, 1888.

now as when first generated—that the primary motions which constitute the existence of the atom might slowly be changing, and even the secondary motions which produce all the effects we can observe—heat, chemic, electric, etc.—might in a slight degree be affected; and I showed the probability that the atoms of the chemical elements were not eternal in existence, but shared with the rest of Creation the attributes of decay and death.

The same idea was expanded at a lecture I delivered at the Royal Institution in 1887, when it was suggested that the atomic weights were not invariable quantities.

I might quote Mr. Herbert Spencer, Sir Benjamin Brodie, Professor Graham, Sir George Stokes, Sir William Thomson (now Lord Kelvin), Sir Norman Lockyer, Doctor Gladstone, and many other English men of science to show that the notion, not necessarily of the decomposability, but at any rate of the complexity of our supposed elements, has long been "in the air" of science waiting to take more definite development. Our minds are gradually getting accustomed to the idea of the genesis of the elements, and many of us are straining for the first glimpse of the resolution of the chemical atom. We are eager to enter the portal of the mysterious region too readily ticketed "Unknown and Unknowable."

Another phase of the dream now demands attention. I come to the earlier glimpses of the electric theory of matter.

Passing over the vaguer speculations of Faraday and the more positive speculations of Sir William Thomson (now Lord Kelvin), one of the earliest definite statements of this theory is given in an article in the Fortnightly Review for June, 1875, by W. K. Clifford, a man who in common with other pioneers shared that "noblest misfortune of being born before his time." "There is great reason to believe," said Clifford, "that every material atom carries upon it a small electric current, if it does not wholly consist of this current."

In 1886, when president of the chemical section of the British association, in a speculation on the origin of matter, I drew a picture of the gradual formation of the chemical elements by the workings of three forms of energy—electricity, chemism, and temperature—on the "formless mist" (protyle[a]), wherein all matter was in the preatomic state—potential rather than actual. In this scheme the chemical elements owe their stability to their being the outcome of a struggle for existence—a Darwinian development by chemical evolution—a survival of the most stable. Those of lowest atomic weight would first be formed, then those of intermediate weight, and finally the

[a] We require a word, analogous to protoplasm, to express the idea of the original primal matter existing before the evolution of the chemical elements. The word I venture to use is composed of προ (earlier than) and ὕλη (the stuff of which things are made).

elements having the highest atomic weights, such as thorium and uranium. I spoke of the "dissociation point" of the elements. "What comes after uranium?" I asked. And I answered back—"The result of the next step will be * * * the formation of * * * compounds the dissociation of which is not beyond the powers of our terrestrial sources of heat." A dream less than twenty years ago, but a dream which daily draws nearer to entire and vivid fulfillment. I will presently show you that radium, the next after uranium, does actually and spontaneously dissociate.

The idea of units or atoms of electricity—an idea hitherto floating intangibly like helium in the sun—can now be brought to earth and submitted to the test of experiment.[a] Faraday, W. Weber, Laurentz, Gauss, Zöllner, Hertz, Helmholtz, Johnstone Stoney, Sir Oliver Lodge, have all contributed to develope the idea, originally due to Weber, which took concrete form when Stoney showed that Faraday's law of electrolysis involved the existence of a definite charge of electricity associated with the ions of matter. This definite charge he called an electron. It was not till some time after the name had been given that electrons were found to be capable of existing separately.

In 1891, in my inaugural address as president of the Institution of Electrial Engineers,[b] I showed that the stream of cathode rays near the negative pole was always negatively electrified, the other contents of the tube being positively electrified, and I explained that "the division of the molecule into groups of electro-positive and electro-negative atoms is necessary for a consistent explanation of the genesis of the elements." In a vacuum tube the negative pole is the entrance and

[a] "The equivalent weights of bodies are simply those quantities of them which contain equal quantities of electricity; * * * it being the electricity which determines the equivalent number, because it determines the combining force. Or, if we adopt the atomic theory or phraseology, then the atoms of bodies which are equivalents to each other in their ordinary chemical action, have equal quantities of electricity naturally associated with them."—Faraday's Experimental Researches in Electricity, par. 869, January, 1834.

"This definite quantity of electricity we shall call the molecular charge. If it were known it would be the most natural unit of electricity."—Clerk Maxwell's Treatise on Electricity and Magnetism, first edition, Vol. I, 1873, p. 311.

"Nature presents us with a single definite quantity of electricity. * * * For each chemical bond which is ruptured within an electrolyte a certain quantity of electricity traverses the electrolyte, which is the same in all cases."—G. Johnstone Stoney, On the Physical Units of Nature, British Association meeting, Section A, 1874.

"The same definite quantity of either positive or negative electricity moves always with each univalent ion, or with every unit of affinity of a multivalent ion."—Helmholtz, Faraday Lecture, 1881.

"Every monad atom has associated with it a certain definite quantity of electricity; every dyad has twice this quantity associated with it; every triad three times as much, and so on."—O. Lodge, On Electrolysis, British Association Report, 1885.

[b] Electricity in Transitu: from Plenum to Vacuum (Journ. Inst. Electrical Engineers, Vol. XX, p. 10, January 15, 1891).

the positive pole the exit for electrons. Falling on a phosphorescent body, yttria, for instance—a collection of Hertz molecular resonators—the electrons excite vibrations of, say, 550 billion times a second, producing ether waves of the approximate length of 5.75 ten-millionths of a millimeter, and occasioning in the eye the sensation of citron-colored light. If, however, the electrons dash against a heavy metal, they produce ether waves of a far higher frequency than light and are not continuous vibrations, but, according to Sir George Stokes, simple shocks or solitary impulses, more like discordant shouts as compared with musical notes.

During that address an experiment was shown which went far to prove the dissociation of silver into electrons and positive atoms.[a] A silver pole was used, and near it in front was a sheet of mica with a hole in its center. The vacuum was very high, and when the poles were connected with the coil, the silver being negative, electrons shot from it in all directions, and passing through the hole in the mica screen formed a bright phosphorescent patch on the opposite side of the bulb. The action of the coil was continued for some hours to volatilize a certain portion of the silver. Silver was seen to be deposited on the mica screen only in the immediate neighborhood of the pole; the far end of the bulb, which had been glowing for hours from the impact of electrons, being free from silver deposit. Here, then, are two simultaneous actions. Electrons or radiant matter shot from the negative pole caused the glass against which they struck to glow with phosphorescent light. Simultaneously, the heavy positive ions of silver, freed from negative electrons and under the influence of the electrical stress, likewise flew off and were deposited in the metallic state near the pole. The ions of metal thus deposited in all cases showed positive electrification.[b]

In the years 1893–1895 a sudden impulse was given to electric vacuum work by the publication in Germany of the remarkable results obtained by Lenard and Röntgen, who showed that the phenomena inside the vacuum tube were surpassed in interest by what took place outside. It is not too much to say that from this date what had been a scientific conjecture became a sober reality.

One important advance in theoretic knowledge has been obtained by Dewar, the successor of Faraday in the classic laboratories of the Royal Institution. Soon after Röntgen's discovery Dewar found that the relative opacity to the Röntgen rays was in proportion to the atomic weights of bodies, and he was the first to apply this principle to settling a debated point in connection with argon. Argon is relatively more opaque to the Röntgen rays than either oxygen, nitrogen,

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[a] In describing the experiment, one of fundamental importance, modern terms are employed.

[b] Proc. Roy. Soc., Vol. LXIX, p. 421.

or sodium, and from this Dewar inferred that the atomic weight of argon was twice its density relative to hydrogen. In the light of to-day's researches on the constitution of atoms it is impossible to overestimate the importance of this discovery.

In 1896 Becquerel, pursuing the masterly work on phosphorescence inaugurated by his illustrious father, showed that the salts of uranium constantly emit emanations, which have the power of penetrating opaque substances and of affecting a photographic plate in total darkness, and of discharging an electrometer. In some respects these emanations, known as "Becquerel rays," behave like rays of light, but they also resemble Röntgen rays. Their real character has only recently been ascertained, and even now there is much that is obscure and provisional in the explanation of their constitution and action.

Following closely upon Becquerel's work came the brilliant researches of M. and Mme. Curie on the radio-activity of bodies accompanying uranium.

Hitherto I have been recounting isolated instances of scientific speculation with apparently little relation to one another. The existence of matter in an ultra gaseous state; material particles smaller than atoms; the existence of electrical atoms or electrons; the constitution of Röntgen rays and their passage through opaque bodies; the emanations from uranium; the dissociation of the elements—all these isolated hypotheses are now focussed and welded into one harmonious theory by the discovery of radium.

> Often do the spirits
> Of great events stride on before the events,
> And in to-day already walks to-morrow.

No new discovery is ever made without its influence ramifying in all directions and explaining much that before had been mystifying. Certainly no discovery of modern times has had such wide-embracing consequences and thrown such a flood of light on broad regions of hitherto inexplicable phenomena as this discovery of M. and Mme. Curie and M. Bémont, who patiently and laboriously plodded along a road bristling with difficulties almost insuperable to others who, like myself, have toiled in similar labyrinths of research. The crowning point of these labors is radium.

Let me briefly recount some of the properties of radium and show how it reduces speculations and dreams, apparently impossible of proof, to a concrete form.

Radium is a metal of the calcium, strontium, and barium group. Its atomic weight, according to C. Runge and J. Precht, is probably about 258. In this case it occupies the third place below barium in my lemniscate spiral scheme of the elements,[a] two unoccupied gaps intervening.

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[a] Proc. Roy. Soc., Vol. LXIII, p. 408.

The spectrum of radium has several well-defined lines; these I have photographed and have also measured their wave lengths. Two especially are strong and characteristic—one at wave length 3649.71, and the other at wave length 3814.58. These lines enable radium to be detected spectroscopically.

The most striking property of radium is its power to pour out torrents of emanations bearing a certain resemblance to Röntgen rays, but differing in important points.

The emanations of radium cause soda glass to assume a violet color, and they produce many chemical changes. Their physiological action is strong, a few milligrams brought near the skin in a few hours producing a wound difficult to heal.

The emanations from radium are of three kinds. One set is the same as the cathode stream, now identified with free electrons—atoms of electricity projected into space apart from gross matter—identical with "matter in the fourth or ultragaseous state," Kelvin's "satellites," Thomson's "corpuscles" or "particles;" Lodge's "disembodied ionic charges, retaining individuality and identity." These electrons are neither ether waves nor a form of energy, but substance possessing inertia (probably electric). Liberated electrons are exceedingly penetrating. They will discharge an electroscope when the radium is 10 feet or more away, and will affect a photographic plate through 5 or 6 millimeters of lead and several inches of wood or aluminum. They are not readily filtered out by cotton-wool; they do not behave as a gas, i. e., they have not properties dependent on intercollisions, mean free path, etc.; they act more like a fog or mist, are mobile and carried about by a current of air to which they give temporary conducting powers, clinging to positively electrified bodies and thereby losing mobility and diffusing on the walls of the containing vessel if left quiet.

Electrons are deviable in a magnetic field. They are shot from radium with a velocity of about one-tenth that of light, but are gradually obstructed by collisions with air atoms, so that some become much slowed, and then are what I formerly called loose and erratic particles, which diffuse about in the air and give it temporary conducting powers. These can turn corners, can be concentrated by mica cones into a bundle and then produce phosphorescence.

Another set of emanations from radium are not affected by an ordinarily powerful magnetic field and are incapable even of passing through thin material obstructions. These emanations have about one thousand times the energy of those radiated by the deflectable particles. They render air a conductor and act strongly on a photographic plate. Their mass is enormous in comparison with that of the electrons, and their velocity is probably as great when they leave the radium, but, in consequence of their greater mass, they are less deflected by

the magnet, are easily obstructed by obstacles, and are sooner brought to rest by collisions with air atoms. The Hon. R. B. Strutt[a] was the first to affirm that these nondeflectable rays are the positive ions moving in a stream from the radio-active body.

Rutherford has shown that these emanations are slightly affected in a very powerful magnetic field, but in an opposite direction to the negative electrons. They are therefore proved to be positively charged bodies moving with great velocity. For the first time Rutherford has measured their speed and mass, and he shows they are ions of matter moving with a speed of the order of that of light.

There is also a third kind of emanation produced by radium. Besides the highly penetrating rays deflected by a magnet, there are very penetrating rays not at all affected by magnetism. These accompany the previous emanations, and are Röntgen rays—ether vibrations—produced as secondary phenomena by the sudden arrest of velocity of the electrons by solid matter, producing a series of Stokesian "pulses" or explosive ether waves shot into space.

Many lines of argument and research tending toward the same point give trustworthy data by which to calculate the masses and velocities of these different particles. I must deal with big figures, but big and little are relative and are only of importance in relation to the limitations of our senses. I will take as the standard the atom of hydrogen gas—the smallest material body hitherto recognized. The mass of an electron is one seven-hundredths of an atom of hydrogen, or 3×10^{-26} gram, according to J. J. Thomson, and its velocity is 2×10^{9} centimeters per second, or two-thirds that of light. The kinetic energy per milligram is 10^{17} ergs, about 3,500,000 foot-tons. Becquerel has calculated that 1 square centimeter of radio-active surface would radiate into space 1 gram of matter in one billion years.

The positively electrified masses or ions are enormously great in comparison with the size of the electron. Sir Oliver Lodge illustrates it thus: If we imagine an ordinary sized church to be an atom of hydrogen, the electrons constituting it will be represented by about 700 grains of sand, each the size of an ordinary full stop (350 positive and 350 negative), dashing in all directions inside, or, according to Lord Kelvin, rotating with inconceivable velocity. Put in another way; the sun's diameter is about 1,500,000 kilometers, and that of the smallest planetoid about 24 kilometers. If an atom of hydrogen be magnified to the size of the sun, an electron will be about two-thirds the diameter of the planetoid.

The extreme minuteness and sparseness of the electrons in the atom account for their penetration. While the more massive ions are stopped by intercollisions in passing among atoms, so that they are

[a] Phil. Trans. R. S., A, 1901, Vol. CXCVI, p. 525.

almost completely arrested by the thinnest sheet of matter, electrons will pass almost unobstructed through ordinary opaque bodies.

The action of these emanations on phosphorescent screens is different. The electrons strongly affect a screen of barium platinocyanide, but only slightly one of Sidot's zinc sulphide. On the other hand, the heavy, massive, nondeflectable positive ions affect the zinc-sulphide screen strongly, and the barium-platinocyanide screen in a much less degree.

Both Röntgen rays and electrons act on a photographic plate and produce images of metal and other substances inclosed in wood and leather, and throw shadows of bodies on a barium-platinocyanide screen. Electrons are much less penetrating than Röntgen rays, and will not, for instance, show easily the bones of the hand. A photograph of a closed case of instruments is taken by radium emanations in three days and by Röntgen rays in three minutes. The resemblance between the two pictures is slight and the differences great.

The power with which radium emanations are endowed of discharging electrified bodies is due to the ionization of the gas through which they pass. This can be effected in many other ways; thus, ionization is communicated to gases faintly by the splashing of water, by flames and red-hot bodies, by ultraviolet light falling on negatively electrified metals, and strongly by the passage of Röntgen rays.

According to Sir Oliver Lodge's electronic theory of matter, a chemical atom or ion has a few extra negative electrons in addition to the ordinary neutral atom, and if these negative electrons are removed it thereby becomes positively charged. The free electron portion of the atom is small in comparison with the main bulk, in the proportion in hydrogen of about 1 to 700. The negative charge consists of superadded or unbalanced electrons—one, two, three, etc., according to the chemical valency of the body—whereas the main bulk of the atom consists of paired groups, equal positive and negative. As soon as the excess electrons are removed the rest of the atom, or ion, acts as a massive positively charged body hanging tightly together. In a high vacuum the induction spark tears the components of a rarified gas apart; the positively charged ions, having great comparative density, are soon slowed down by collisions, while the electrons are driven from the negative pole with an enormous velocity, depending on the initial electromotive force and the pressure of gas inside the tube, but approaching at the highest exhaustions half that of light.

After leaving the negative pole the electrons meet with a certain resistance in a slight degree by physical collisions, but principally by reunion with the positive ions.

Since the discovery of radium and the identification of one set of its emanations with the cathode stream or radiant matter of the vacuum tube, speculation and experiment have gone hand in hand, and the

two-fluid theory of electricity is gradually replaced by the original one-fluid theory of Franklin. On the two-fluid theory the electrons constitute free negative electricity and the rest of the chemical atom is charged positively, although a free positive electron is not known. It seems to me simpler to use the original one-fluid theory of Franklin, and to say that the electron is the atom or unit of electricity. Fleming uses the word "coelectrons" to express the heavy positive ion after separation from the negative electron. "We can no more," he says, "have anything which can be called electricity apart from corpuscles than we can have momentum apart from moving matter." A so-called negatively charged chemical atom is one having a surplus of electrons, the number depending on the valency, whilst a positive ion is one having a deficiency of electrons. Differences of electrical charge may thus be likened to debits and credits in one's banking account, the electrons acting as current coin of the realm. On this view only the electron exists; it is the atom of electricity, and the words positive and negative, signifying excess and defect of electrons, are only used for convenience of old-fashioned nomenclature.

The electron theory fits and luminously explains Ampère's idea that magnetism is due to a rotating current of electricity round each atom of iron; and following these definite views of the existence of free electrons has arisen the electronic theory of matter. It is recognized that electrons have the one property which has been regarded as inseparable from matter—nay, almost impossible to separate from our conception of matter—I mean inertia. Now, in that remarkable paper of J. J. Thomson's, published in 1881, he developed the idea of electric inertia (self-induction) as a reality due to a moving charge. The electron therefore appears only as apparent mass by reason of its electro-dynamic properties, and if we consider all forms of matter to be merely congeries of electrons the inertia of matter would be explained without any material basis. On this view the electron would be the "protyle" of 1886, whose different groupings cause the genesis of the elements.

There is one more property of the emanations of radium to bring before your notice. I have shown that the electrons produce phosphorescence of a sensitive screen of barium platinocyanide and the positive ions of radium produce phosphorescence of a screen of zinc blende.

If a few minute grains of radium salt fall on the zinc-sulphide screen the surface is immediately dotted with brilliant specks of green light. In a dark room, under a microscope with a $\frac{2}{3}$-inch objective, each luminous spot shows a dull center surrounded by a diffused luminous halo. Outside the halo the dark surface of the screen scintillates with sparks of light. No two flashes succeed on the same spot, but are

scattered over the surface, coming and going instantaneously, no movement of translation being seen.

If a solid piece of a radium salt is brought near the screen, and the surface examined with a pocket lens magnifying about 20 diameters, scintillating spots are sparsely scattered over the surface. Bringing the radium nearer the screen, the scintillations become more numerous and brighter, until when close together the flashes follow so quickly that the surface looks like a turbulent luminous sea. When the scintillating points are few, there is no visible residual phosphorescence and the successive sparks appear "atoms of intensest light," like stars on a black sky. What to the naked eye seems like a uniform "milky way," under the lens becomes a multitude of stellar points flashing over the whole surface.

"Polonium" basic nitrate, actinium, and radio-active platinum produce a similar effect on the screen, but the scintillations are fewer. In a vacuum the scintillations are as bright as in air, and, being due to interatomic motion, they are not affected by extremes of low temperature; in liquid hydrogen they are as brilliant as at the ordinary temperature.

A convenient way to show these scintillations is to fit the blende screen at the end of a brass tube with a speck of radium salt in front about a millimeter off, and to have a lens at the other end. I propose to call this little instrument the "Spinthariscope," from the Greek word σπινθαρίς,[a] a scintillation.

It is difficult to estimate the number of flashes of light per second. With the radium about five centimeters off the screen the flashes are barely detectable, not more than one or two per second. As the distance of the radium diminishes, the flashes become more frequent, until at one or two centimeters they are too numerous to count, although it is evident this is not of an order of magnitude inconceivably great.

Practically the whole of the luminosity on the blende screen, whether due to radium or "polonium," is occasioned by emanations which will not penetrate card. These are the emanations which cause the scintillations, and the reasons why they are distinct on the blende and feeble on the platino-cyanide screen is that with the latter the sparks are seen on a luminous ground of general phosphorescence which renders the eye less able to see the scintillations.

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[a] Ενθ ἐκ νηὸς ὄρουσεν ἄναξ, ἑκάεργος Ἀπόλλων,
ἀστέρι εἰδόμενος, μέσω ἡματὶ τοῦ δ' ἀπὸ πολλαὶ
σπινθαρίδες πωτωντο, σέλας δ' εις οὐρανὸν ἱκεν'

(Here from the ship leaped the far-darting Apollo, like a star at midday, while from him flitted scintillations of fire, and the brilliancy reached to heaven.)—Homer's Hymn to Apollo, lines 440–442.

It is probable that in these phenomena we actually witness the bombardment of the screen by the positive ions hurled off by radium with a velocity of the order of that of light. Each particle is rendered apparent only by the enormous extent of lateral disturbance produced by its impact on the sensitive surface, just as individual drops of rain falling on a still pool are not seen as such, but by reason of the splash they make on impact, and the ripples and waves they produce in ever-widening circles.

Indulging in a "scientific use of the imagination," and pushing the hypothesis of the electronic constitution of matter to what I consider its logical limit, we may be, in fact, witnessing a spontaneous dissociation of radium—and we begin to doubt the permanent stability of matter. The chemical atom may be actually suffering a katabolic transformation, but at so slow a rate that, supposing a million atoms fly off every second, it would take a century for weight to diminish by one milligram.

It must never be forgotten that theories are only useful so long as they admit of the harmonious correlation of facts into a reasonable system. Directly a fact refuses to be pigeonholed and will not be explained on theoretic grounds, the theory must go, or it must be revised to admit the new fact. The nineteenth century saw the birth of new views of atoms, electricity, and ether. Our views to-day of the constitution of matter may appear satisfactory to us, but how will it be at the close of the twentieth century? Are we not incessantly learning the lesson that our researches have only a provisional value? A hundred years hence shall we acquiesce in the resolution of the material universe into a swarm of rushing electrons?

This fatal quality of atomic dissociation appears to be universal and operates whenever we brush a piece of glass with silk; it works in the sunshine and raindrops, and in the lightnings and flame; it prevails in the waterfall and the stormy sea. And although the whole range of human experience is all too short to afford a parallax whereby the date of the extinction of matter can be calculated, protyle, the "formless mist," once again may reign supreme, and the hour hand of eternity will have completed one revolution.

THE ATOMIC THEORY.[a]

By Prof. F. W. Clarke, D. Sc.

One hundred years ago, on October 21, 1803, John Dalton gave this society the first announcement of his famous atomic theory. It was only a slight preliminary notice, a mere note appended to a memoir upon another subject, and it attracted little or no attention. In 1804 Dalton communicated his discovery to Dr. Thomas Thomson, who at once adopted it in his lectures, and in 1807 gave it still wider publicity in a text-book. A year later Dalton published his New System of Chemical Philosophy, and since then the history of chemistry has been the history of the atomic theory. To celebrate Dalton's achievement, to trace its influence upon chemical doctrine and discovery, is the purpose of my lecture. It is an old story, and yet a new one; for every year adds something to it, and the process of development shows no signs of nearing an end. A theory that grows and is continually fruitful can not be easily supplanted. Despite attacks and criticisms, Dalton's generalization still holds the field; and from it, as from a parent stem, spring nearly all the other accepted theories of chemistry.

Every thought has its ancestry. Let us briefly trace the genealogy of the atomic theory. In the very beginnings of philosophy men sought to discover the nature of the material universe and to bring unity out of diversity. Is matter one thing or many? Is it continuous or discrete? These questions occupied the human mind before recorded history began, and their vitality can never be exhausted. Final answers may be unattainable, but thought will fly beyond the boundaries of knowledge to bring back, now and then, truly helpful tidings.

To the early Greek philosophers we must turn for our first authentic statements of an atomic theory. Other thinkers in older civilizations doubtless went before them; perhaps in Egypt or Babylonia, but of them we have no certain knowledge. There is a glimpse of something in India, but we can not say that Greece drew her inspiration thence. For us Leucippus was the pioneer, to be followed later by Democritus

[a] The Wilde Lecture, delivered May 19, 1903, by Professor Clarke before the Manchester Literary and Philosophical Society. Reprinted from Memoirs and Proceedings of the Society, Manchester, England, vol. 47, Part IV, No. 11, May 29, 1903.

and Epicurus. Then, in lineal succession, came the Roman, Lucretius, who gave to the doctrine the most complete statement of all. In the thought of these men the universe was made up of empty space in which swam innumerable atoms. These were inconceivably small, hard particles of matter, indivisible and indestructible, of various shapes and sizes, and continually in motion. From their movements and combinations all sensible matter was derived. Except that the theory was purely qualitative and nonmathematical in form it was curiously like the molecular hypothesis of modern physics, only with an absolute vacuum where an intermediary ether is now assumed. This notion of a vacuum was repellant to many minds; to conceive of a mass of matter so small that there could be none smaller was unreasonable; and hence there arose the interminable controversy between plenists and atomists which has continued to our own day.

It is, however, essentially a metaphysical controversy, and some writers have ascribed it to a peculiar distinction between two classes of minds. The arithmetical thinker deals primarily with number, which is, in its nature, discontinuous, and to him a material discontinuity offers no difficulties. The geometer, on the other hand, has to do with continuous magnitudes, and a limited divisibility of anything in space is not easy for him to conceive. But be this as it may, the controversy was one of words rather than of realities, and its intricacies have little interest for the scientific student of to-day. It is always easier to reason about things as we imagine they ought to be, than about things as they really are, and the latter procedure became practicable only after experimental science was pretty far advanced. The Greeks were deficient in physical knowledge, and, therefore, their speculations remained speculations only, mere intellectual gymnastics of no direct utility to mankind. They sought to determine the nature of things by the exercise of reason alone, whereas science, as we understand it, being less confident, seeks mainly to coordinate evidence and to discover the general statement which shall embrace the largest possible number of observed relations. The man of science may use the metaphysical method as a tool, but he does so with the limitations of definite, verifiable knowledge always in view. Intellectual stimulants may be used temperately, but they need not be discarded altogether.

From the time of Lucretius until the seventeenth century of our era the atomistic hypothesis received little serious attention. The philosophy of Aristotle governed all the schools of Europe, and scholastic quibblings took the place of real investigation. All scholarship lay under bondage to one master mind, and it was not until Galileo let fall his weights from the leaning tower of Pisa that the spell of the Stagirite was broken. Experimental science now came to the fore, and it was seen that even Aristotelian logic must verify its premises.

The authority of evidence began to replace the authority of the schools.

Early in the seventeenth century the atomic philosophy of Epicurus was revived by Gassendi, who was soon followed by Boyle, by Newton, and by many others. One other important step was taken also. Boyle, in his Sceptical Chymist, gave the first scientific definition of an element, a conception which was more fully developed by Lavoisier later, but which received its complete modern form only after Davy had decomposed the alkalies and shown the true nature of chlorine. Without this preliminary work of Boyle and Lavoisier, Dalton's theory would hardly have been possible. An elementary atom can be given no real definition unless we have some notion of an element to begin with. But the strongest impulse came from Newton, who accepted atomism in clear and unmistakable terms.

Coming before Newton, Descartes had rejected the atomic hypothesis, holding that there could be no vacuum in the universe and making matter essentially synonymous with extension. True, Descartes, in his famous theory of vortices, imagined whirling particles of various degrees of fineness; but they were not atoms as atoms and molecules are now conceived. It may be dangerous to pick out landmarks in history and to assert that such and such a movement began at such and such a time. Nevertheless, we may fairly say that the turning point in physical philosophy was Newton's discovery of gravitation, for that indicated mass as the fundamental property of matter. For any given portion of matter which we can segregate and identify extension is variable and mass is constant; when that conclusion was established the dominance of atomism became inevitable. Boyle, Newton, and Lavoisier were legitimate precursors of Dalton, but whether Boscovich should be so considered is more than doubtful. His points of force were too abstract a conception to admit of direct application in the solution of real problems. Dalton certainly owed nothing to Boscovich, and would just as surely have developed his theory had the brilliant Dalmatian never written a line.

To Boyle and Newton the atomic hypothesis was a question of natural philosophy alone, for in their day chemistry as a quantitative science had hardly begun to exist. Attempts were soon made, however, to give it chemical application, and the first of these which I have been able to find was due to Emanuel Swedenborg. This philosopher, whose reputation as a man of science has been overshadowed by his fame as a seer and theologian, published in 1721 a pamphlet upon chemistry, which is now more easily accessible in an English translation of relatively recent date.[a] It consists of chapters from a larger unpublished work, and really amounts to nothing more than a

[a] Some Specimens of a Work on the Principles of Chemistry, with other Treatises. London, 1847. Originally published at Amsterdam, in Latin.

sort of atomic geometry. From geometric groupings of small, concrete atoms the properties of different substances are deduced, but in a way which is more curious than instructive. Between the theory and the facts there is no obvious relation. The book was absolutely without influence upon chemical thought or discovery, and therefore it has escaped general notice. It is the prototype of a class of speculative treatises, considerable in number, some of them recent, and all of them futile. They represent efforts which were premature and for which the fundamental support of experimental knowledge was lacking.

In 1775 Dr. Bryan Higgins, of London, published the prospectus of a course of lectures upon chemistry, in which the atomic hypothesis was strongly emphasized. It was still, however, only a hypothesis, quite as ineffectual as Swedenborg's attempt, and it led to nothing. Dr. Higgins recognized seven elements—earth, water, alkali, acid, air, phlogiston, and light—each one consisting of "atoms homogeneal," these being "impenetrable, immutable in figure, inconvertible," and all "globular, or nearly so." He speculated upon the attractions and repulsions between these bodies, but he seems to have solved no problem and to have suggested no research. William Higgins, on the other hand, whose work appeared in 1789, showed more insight into the requirements of true science and had some notions concerning definite and multiple proportions. His conception of atomic union to form molecules was fairly clear, but the distinct statement of a quantitative law was just beyond his reach. In 1814, however, when Dalton's discoveries were widely known and accepted, Higgins published a reclamation of priority.[a] In this, with much bitterness, he claims to have completely anticipated Dalton, a claim which no modern reader has been able to allow. In Robert Angus Smith's Memoir of John Dalton and History of the Atomic Theory,[b] the work of Bryan and William Higgins is quite thoroughly discussed, and therefore we need not consider the matter any more fully now. We see that atomic theories were receiving the attention of chemists long before Dalton's time, although none of them went much beyond the speculative stage or was given serviceable form. They were dim foreshadowings of science; nothing more.

In order that a new thought shall be acceptable, certain prerequisite conditions must be fulfilled. If the ground is not prepared, the seed can not be fruitful; if men are not ready, no harvest will be reaped. Only when the time is ripe, only when long lines of evidence have begun to converge, can a new theory command attention. Dalton's

[a] Experiments and Observations on the Atomic Theory and Electrical Phenomena. By Williams Higgins, esq., etc. Dublin, 1814.

[b] Memoirs of the Literary and Philosophical Society of Manchester, second series, vol. 13, 1856.

opportunity came at the right moment, and he knew how to use it well. Elements had been defined; the constancy of matter was established; pneumatic chemistry was well developed, and great numbers of quantitative analyses awaited interpretation. The foundations were ready for the master builder, and Dalton was the man. His theory could at once be tested by the accumulated data, and when that had been done it was found to be worthy of acceptance.

It is not my purpose to discuss in detail the processes of Dalton's mind. The story is told in his own notebooks, which have been given to the public by Roscoe and Harden,[a] and it has been sufficiently discussed by others. We now know that Dalton was thoroughly imbued with the corpuscular ideas of Newton and that, when studying the diffusion of gases, he was led to the belief that the atoms of different substances must be different in size. Upon applying this hypothesis to chemical problems he discovered that these differences were in one sense measurable and that to every element a single, definite, combining number, the relative weight of its atom, could be assigned.

From this, the law of definite proportions logically followed, for fractions of atoms were inadmissible; and the law of multiple proportions, which Dalton worked out experimentally, completed the generalization. The conception that all combination must take place in fixed proportions was not new, and, indeed, despite the objections of Berthollet, was generally assumed; but the atomic theory gave a reason for the law and made it intelligible. The idea of multiple proportions had also occurred, although incompletely, to others; but the determination of atomic weights was altogether original and novel. The new atomic theory, which figured chemical union as a juxtaposition of atoms, coordinated all of these relations and gave to chemistry for the first time an absolutely general quantitative basis. The tables of Richter and Fischer, who preceded Dalton, dealt only with special cases of combination, but they established regularities which rendered easier the acceptance of the new and broader teachings. The earlier atomic speculations were all purely qualitative and incapable of exact application to specific problems; Dalton created a working tool of extraordinary power and usefulness. Between the atom of Lucretius and the Daltonian atom the kinship is very remote.

Dalton was not a learned man, in the sense of mere erudition, but perhaps his limitations did him no harm. Too much learning is sometimes in the way, and clogs the flight of that imagination by which the greatest discoveries are made. The man who could not see the forest because of the trees was a good type of that scholarship which never rises above petty details. It may compile encyclopaedias, but it can

[a] A New View of the Origin of Dalton's Atomic Theory, etc. By Sir Henry E. Roscoe and Arthur Harden. London, 1896. See also Debus, in Zeits. Physikal. Chem., Bd. 20, p. 359, and a rejoinder by Roscoe and Harden in Bd. 22, p. 241.

not generalize. In some ways, doubtless, Dalton was narrow, and he failed to recognize the improvements which other men soon introduced into his system. The chemical symbols which he proposed were soon supplanted by the better formulæ invented by Berzelius, and his views upon the densities of gases were set aside by the more exact work of Gay Lussac, which Dalton never fully appreciated. As an experimenter he was crude and excelled by several of his contemporaries; his tables of atomic weights, or rather equivalents, were only rough approximations to the true values. These defects, however, are only spots upon the sun and in no wise diminish his glory. Dalton transformed an art into science, and his influence upon chemistry was never greater than it is to-day. The truth of this statement will appear when we trace, step by step, the development of chemical doctrine. The guiding clue, from first to last, is Dalton's atomic theory.

Although Dalton first announced his theory in 1803, the publication of his "system" in 1808 marks the culmination of his labors. The memorable controversy between Proust and Berthollet had by this time exhausted its force, and nearly all chemists were satisfied that the law of definite or constant proportions must be true. The idea of multiple proportions was also easily accepted; and as for the combining numbers, they, after various revisions, came generally into use. The atomic conception, however, made its way more slowly, for the fear of metaphysics still governed many acute minds. Davy especially was late in yielding to it, but in time even his conversion was effected. Thomson, as we have already noted, was the earliest and most enthusiastic disciple of the new system, and Wollaston, although cautiously preferring the term "equivalent" to that of atomic weight, made useful contributions to the theory. These names mark the childhood of the doctrine before its vigorous growth had thoroughly begun.

The development of the atomic theory followed two distinct lines, the one chemical, the other physical, in direction. On the chemical side the leader was Berzelius, who began in 1811 the publication of his colossal researches upon definite proportions. At first he seems to have been influenced by Richter rather than by Dalton, but that bias was only temporary. For more than thirty years Berzelius continued these labors, inventing symbols, establishing formulæ, and determining atomic weights. He, above all other men, made the atomic theory applicable to general use, a universal tool suited to practical purposes. Turner, Penny, Erdmann, and others did noble work of the same order, but Berzelius overshadowed them all. Throughout his long career he was almost the dictator of chemistry.

It was on the physical side, however, that the theory of Dalton was most profoundly modified. First came the researches of Gay Lussac, who, in 1808, showed that combination between gases always took place in simple relations by volume, and also that all gaseous densities were proportional either to the combining weights of the several sub-

stances, or to rational multiples thereof. In 1811 Avogadro generalized the new evidence and brought forward the great law which is now known by his name. Equal volumes of gases, under like conditions of temperature and pressure, contain equal numbers of molecules. Mass and volume were thus covered by one simple expression, and both were connected with the weights of the fundamental atoms. Avogadro, moreover, distinguished clearly between atoms and molecules, a distinction which is of profound importance to chemistry, although it is not always properly appreciated by students of physics. The molecule of to-day, which is usually, but not always, a cluster of atoms, is identical with the atom of the pre-Daltonian philosophers; while the chemical unit represents a new order of divisibility which the ancients could never have imagined. A molecule of water was easily conceived by them, but its decomposition into smaller and simpler particles of oxygen and hydrogen, the chemical atoms, was far beyond the range of their knowledge. That the distinction is not always borne in mind by physicists is illustrated by the fact that in Clerk Maxwell's article "Atom," in the Encyclopædia Britannica, Dalton is not even mentioned, and the phenomena there selected for discussion are molecular only.

Maxwell was surely not ignorant of the difference between atoms and molecules, but his knowledge had not reached the point of complete realization. His thought was of molecules, and so Maxwell unconsciously neglected the real subject of his chapter—the atom. Of late years many essays upon the atomic theory have been written from the physical side, and few of them have been free from this particular ambiguity. At first a similar error was committed by chemists, who paid small attention to Avogadro's law, and so the latter failed to exert much influence upon chemical thought until more than forty years after its promulgation. The relation discovered by Dulong and Petit in 1819, that the specific heat of a metal was inversely proportional to its atomic weight, was more speedily accepted; but even this law did not receive its full application until many years later. To apply either of these laws to chemical theory involved a clearer discrimination between atomic weights and equivalents than was possible at the beginning. A long period of doubt and controversy was to work itself out before the full force of the physical evidence could be appreciated. Mitscherlich's researches upon isomorphism were more fortunate, and gave immediate help in the determination of atomic weights and the settlement of formulæ. For the moment we need only note that the chemical atom was the underlying conception by means of which all these lines of testimony were to be unified.

From Dalton and Gay-Lussac to Frankland and Cannizzaro was a time of fermentation, discussion, and discovery. In chemistry, contrary to the saying of the preacher, there were many new things under the sun, and some of the discoveries were most suggestive. First, it

was found that certain groups of atoms could be transferred from compound to compound, almost as if they were veritable elements; and radicles, such as ammonium, cyanogen, and benzoyl, were generally recognized. I say "groups of atoms" advisedly, for as such they were regarded, and they could hardly have been interpreted otherwise. Then came the discovery of isomerism; of the fact that two substances could be strikingly different, and yet composed of the same elements in exactly the same proportions. This was only explicable upon the supposition that the atoms were differently arranged within the isomeric molecules, and it led investigators more and more to the study of chemical or molecular structure. Without the atomic theory the phenomena would have been hopelessly bewildering; with its aid they were easy to understand and fertile in suggestions for research. Still another link in the chain of chemical reasoning was forged by Dumas when he proved that the hydrogen of organic compounds was often replaceable, atom for atom, by chlorine. Sometimes the replacement was complete, sometimes it was only partial, and the latter cases were the most significant. In acetic acid, for example, one, two, or three fourths of the hydrogen could be successively replaced, but the last fourth was permanently retained. Hydrogen, then, was combined in acetic acid in two different ways, one part yielding its place to chlorine, the other being unaffected. This behavior was soon found to be by no means exceptional; indeed, it was very common, and it opened a new line of attack upon the problems of chemical constitution. The existence of radicles, the formation of isomers, and the substitution of one element by another were facts which strengthened the atomic theory and seemed to be incapable of reasonable interpretation upon other terms. Their connection with one another, however, was not well understood, and wearisome discussions preceded their coordination under one general law.

With the tedious controversies which distracted chemists between 1830 and 1850 we have nothing now to do; they were important in their day, but they do not come within the scope of the present argument. Theory after theory was advanced, prospered for a time, and then decayed, and chemical literature is crowded with their fossil remains. Each one, doubtless, indicated an advance in knowledge; but each one also exaggerated the importance of some special set of relations and so overshot the mark. During this period, however, Faraday discovered the law of electrolysis which is now known by his name, and the chemical equivalents were thereby given another extension of meaning. The electro-chemical theories of Berzelius had fallen to the ground, but Faraday's law came as a permanent addition to the physical side of chemistry.

During the sixth decade of the nineteenth century two important forward steps were taken. The kinetic theory of gases gave new force

to Avogadro's law, and made its complete recognition by chemists necessary. Atoms, molecules, equivalents, and atomic weights needed to be more sharply defined, and in this work many chemists shared. Berzelius had proposed a system of atomic weights which differed, except in the value taken for its base, but little from the one now in use. This was abandoned for a table devised by Gmelin, in which the laws of Avogadro and of Dulong and Petit were almost if not entirely ignored. Laurent and Gerhardt attempted to reform the system, but it was left for Cannizzaro, in 1858, to succeed. By doubling some of the currently accepted atomic weights order was introduced into the prevailing chaos, and the chemical constants were brought into harmony with the physical laws. The modern atomic weights and our present chemical notation may be dated from this time, even though the preliminary anticipations of them were neither few nor inconspicuous.

The second great step forward was accomplished through the labors of several men. Frankland and Kekulé were foremost among them, but Couper, Odling, Williamson, Wurtz, and Hofmann all contributed their share to the upbuilding of a new chemistry of which the doctrine of valency was the corner stone. A new property of the chemical atom was brought to light, and structural or rational formulæ became possible. Each atom was shown to have a fixed capacity for union with other atoms, a capacity which could be given numerical expression, and from this discovery important consequences followed. An atom of hydrogen unites with one other atom only; the atom of oxygen may combine with two; that of nitrogen with three or five; while carbon has capacity for four. All unions of atoms to atoms within a molecule are governed by conditions of this order, and the limitations thus imposed determine the possibilities of combination in a given class of compounds. In organic chemistry the conception of valency has been most fruitful, and it has shown the prophetic power which is characteristic of all good theories. It explains radicles and isomers; it predicts whole classes of compounds in advance of their actual discovery; and it has guided economic investigations from which great industries have sprung. The former partial theories regarding chemical constitution fell into their proper places under the new generalization, for that was broad enough to comprehend them all. All constitutional chemistry depends upon this property of the atoms, and any other adequate foundation for it would be difficult to find.

I have said that the discovery of valency explained the phenomena of isomerism. Indeed, it enabled chemists to foresee the existence of new isomers and it established the conditions under which such compounds could exist. And yet, in one direction at least, its power was limited and substances were found which the theory could not interpret. Tartaric acid, for example, exists in two modifications, differing in

crystalline form and in their action upon polarized light. One acid was dextrorotatory, the other lævorotatory, while a mixture of the two in equal proportions was neutral to the polarized beam, and gave no rotation at all. Their crystals exhibited a similar difference in the arrangement of certain planes, one set being right-handed, the other left-handed; and each crystal resembled its isomer like a reflection in a mirror, alike, but reversed. For a long time this physical isomerism, as it was called, remained inexplicable, for the rules of valency gave to both molecules the same structure and offered no hint as to the cause of the difference. Structural formulæ, however, said nothing of the arrangement of the atoms in tridimensional space and it was soon suspected that the root of the difficulty was here. The mere linking of the atoms with one another could be represented in a single plane, but that was obviously an imperfect symbolism.

In 1874 van't Hoff and Le Bel, working independently of each other, suggested a solution of the problem. One simple assumption was enough; merely that the quadrivalent carbon atom was essentially a tetrahedron or, more precisely, that its four units of chemical attraction were exerted from a common center in the direction of four tetrahedral angles. Atoms of that kind could be built up into structures in which right-handedness and left-handedness of arrangement appeared, provided only that each one was united with four other atoms or groups all different in nature. Stereochemistry was born, the anomalies vanished, and many new substances showing optical and crystalline properties analogous to those of tartaric acid were soon prepared. The theory of van't Hoff and Le Bel was fertile, and therefore it was justified; it interpreted another set of phenomena, but in order to do so something like atomic form had first to be assumed. It was only a new extension of Dalton's atomic theory, but it has suggested a future development of extraordinary significance. If we can determine, not merely the linking of the atoms, but also their arrangement in space, we should be able, sooner or later, to establish a connection between chemical composition and crystalline form. The architecture of the molecule and the architecture of the crystal must surely in some way be related. But the problem is exceedingly complex, and we may have to wait many years before we reach its solution. The atomic theory still has room to grow.

Let us now turn back in time and consider another phase of our subject. In 1815 Prout suggested that the atomic weights of all the elements were even multiples of that of hydrogen. It was only a speculation on the part of Prout, and yet it led to important consequences, for it opened a discussion upon the nature of the chemical elements, and it pointed to hydrogen as the primal matter of the universe. Prout's hypothesis, therefore, became a subject of controversy. It found many supporters and also many antagonists; but, fortunately,

one aspect of it was capable of experimental investigation. Some of the most exact and elaborate determinations of atomic weight have been made with the direct purpose of testing the truth or falsity of Prout's speculation, and science thereby has been notably enriched. The marvelous researches of Stas, for instance, had this specific object in view. The verdict was finally unfavorable to Prout. At least, the best measurements fail to support his idea; but it still has advocates who believe that the experimental data are vitiated by unknown errors, and that future investigations will reverse the decision. In science there is no court of last appeal.

Prout's hypothesis, then, stimulated the determination of atomic weights, and so helped us to a more accurate knowledge of them. It also led to a search for other relations between these constants, and thus paved the way for important discoveries. Döbereiner, Kremers, Dumas, Pettenkofer, Cooke, and many other chemists published memoirs upon this theme, but not one of them was general or conclusive.[a] Groups of elements were compared and relations were brought to light, but an exhaustive study of the question was hardly possible until after Cannizzaro had revised the atomic weights and indicated their proper values.

In 1865 Newlands presented before the London Chemical Society a communication upon the law of octaves, in which he showed that the elements, when arranged in the order of their atomic weights, exhibited a certain regular recurrence of properties. Unfortunately, his views were not given serious attention, and even met with ridicule, but they contained the germ of the great truth. It was reserved for the Russian, Mendeléeff, four years later, to completely formulate the famous periodic law.

Mendeléeff arranged the elements in tabular form, still following the order of their atomic weights. A periodic variation of their properties, including the property of valency, at once became evident; and although the scheme was, and still is, open to some criticism, its importance could hardly be denied. In the table certain gaps appeared, presumably belonging to unknown elements, and for three of these some remarkable predictions were made. The hypothetical elements were described by Mendeléeff, their atomic weights were assigned, and their physical properties foretold, and in due time the prophecies were verified. The three metals gallium, scandium, and germanium—have since been discovered, and they correspond very closely with Mendeléeff's anticipations. His general conclusion was that all of the physical properties of the chemical elements are periodic functions of their atomic weights, and this conclusion, I think, is no

[a] A very full account of these attempts is given in Venable's book, The Development of the Periodic Law, published at Easton, Pa., in 1896.

longer seriously doubted. The curves of atomic volumes and melting points which Lothar Meyer afterwards constructed give strong support to this view.

The periodic system, then, gives to the numbers discovered by Dalton a much more profound significance than he ever imagined, and is destined to connect a great mass of physical data in one general law. That law we now see, "as in a glass, darkly;" its complete mathematical expression is yet to be found, but I believe that it will be fully developed within the near future. We may have a spiral curve to deal with, as in the schemes proposed by Stoney or by Crookes, or else a vibratory expression like that suggested by Emerson Reynolds in his presidential address before the Chemical Society last year; but in some form the periodicity of the elements must be recognized, and one set of relations will connect them all.

In the arrangement proposed by Reynolds the inert gases, the elements of zero valency, appear at the nodes of a vibrating curve—a circumstance which gives this method of presentation a peculiar force; but for the consideration of physical properties the curves drawn by Lothar Meyer seem likely to be the most useful. In one respect, however, the periodic system is still defective—it fails to take adequately into account the numerical relations between the atomic weights, a phase of the problem which should not be ignored. Such relations exist; some of them have been indicated by your distinguished fellow-member, Doctor Wilde; and, elusive as they may seem to be, they are surely not meaningless. The final law must cover the entire ground, and then atomic weights, physical properties, and valency will be completely correlated. Prout's hypothesis is discredited, and yet it may prove to be a crude first approximation to some deeper truth, as the probability calculations of Mallet[a] and of Strutt[b] would seem to indicate. The approaches of the atomic weights to whole numbers are too close and too frequent to be regarded as purely accidental. But this is aside from our main question. The real point to note is that the physical properties of the elements are all interdependent, and that the fundamental constants are the atomic masses.

Do I seem to exaggerate? Then look for a moment at the present condition of physical chemistry, and see how moderate my statements really are. We have not only the laws already mentioned, of Avogadro, of Dulong and Petit, of Faraday and of Mendeléeff, but also a multitude of relations connecting the physical constants of bodies with their chemical character. Even the wave lengths of the spectral lines are related to the atomic weights of the several elements, as has been shown by the researches of Runge and his colleagues, of Rummel,[c]

[a] Phil. Trans., vol. 171, 1881, p. 1003.
[b] Phil. Mag. (6), 1, p. 311.
[c] Proc. Roy. Soc. Victoria, vol. 10, Part. 1, p. 75.

and of Marshall Watts.[a] If we try to study the specific gravity of solids or liquids, the only clews to regularity are furnished by the atomic ratios. Atomic and molecular volumes give us the only approximations to anything like order. Similarly, we speak of atomic and molecular refraction, of molecular rotation for polarized light, of molecular conductivity, and the like. In Trouton's law the latent heat of vaporization of any liquid becomes a function of the molecular weight. And, finally, all thermochemical measurements are meaningless until they have been stated in terms of gram molecular weights; then system begins to appear. Chaos rules until the atomic or molecular weight is taken into account; with that considered, the reign of order begins.

Even to the study of solutions the same conditions apply. Substances in solution exert pressure, and in this respect they closely resemble gases. Van't Hoff has shown that equal volumes of solutions, having under like conditions equal osmotic pressures, contain equal numbers of molecules, and thus Avogadro's gas law is curiously paralleled. The two laws are even equivalent in their anomalies. The abnormal density of a gas is explained by its dissociation, and the variations from van't Hoff's law are explicable in the same way. The theory of ionic or electrolytic dissociation, proposed by Arrhenius, shows that certain substances, when dissolved, are split up into their ions, and through this conception the analogy between gases and solutions is made absolutely complete. The ions, however, are atoms or groups of atoms, and just as Avogadro's law is applied to the determination of molecular weights among gases, so van't Hoff's rules enable us to measure the molecular weights of substances in solution. The atom, the molecule, and the molecular weight enter into all of these new generalizations. In short, if we take the atomic theory out of chemistry we shall have little left but a dust heap of unrelated facts.

I have now indicated briefly, and in outline only, the influence of the atomic theory upon the development of chemical thought. Details have been purposely omitted; the salient facts are enough for my purpose, and they make, at least for chemists, an exceedingly strong case. The convergence of the testimony is remarkable, and when we add to the chemical evidence that which is offered by physics, the theory becomes overwhelmingly strong. This side of the question I can not attempt to discuss, but I may in passing just refer to Professor Rücker's presidential address before the British Association in 1901, which covers the ground admirably. The atomic theory has had no better vindication.

And yet from time to time we are told that the theory has outlived its usefulness, and that it is now a hindrance rather than a help to

[a] Phil. Mag. (6), 5, 203.

science. Some of the objectors are quite dogmatic in their utterances; some only seek to evade the theory without going to the extreme of an absolute denial, and still others, more timid, assume an apologetic tone, as if the atom were something like a poor relation—to be recognized and tolerated, but not to be encouraged too far. Now, caution is a good thing if it is not allowed to degenerate into indecision; when that happens mental obscurity is the result. In science we must have intellectual resting places; something to serve as a foundation for our thinking; something concrete and tangible in form. No theory is immune against hypercriticism; none is absolute and final. With these considerations borne in mind we may ask whether a doctrine is serviceable or not and we can use it without fear. When we say that matter, as we know it, behaves as if it were made up of very small, discrete particles we do not lose ourselves in metaphysics, and we have a definite conception which can be applied to the correlation of evidence and the solution of problems. Objections count for nothing against it until something better is offered in its stead—a condition which the critics of the atomic theory have so far failed to fulfill. They give us no real substitute for it, no other working tool, and so their objections, which are too often metaphysical in character, command little serious attention. Criticism is useful just so far as it helps to clarify our thinking; when it becomes a mere agent of destruction it loses force.

Broadly speaking, then, the modern critics of the atomic theory have shaken it but little. Still, some serious attempts have been made toward forming an alternative system of chemistry, or at least a system in which the atom shall not avowedly appear. The most serious and perhaps the most elaborate of these devices was that brought forward in 1866 by Sir Benjamin Brodie[a] in his Calculus of Chemical Operations, which he defended later (1880) in a little book entitled Ideal Chemistry. In this curious investigation Brodie tries to avoid hypotheses and to represent chemical acts as operations upon the unit of space by which weights are generated. This notion is a little difficult to grasp, but Brodie's procedure was perfectly legitimate. His one fundamental assumption is that hydrogen is so generated by a single operation, and upon this he erects a system of symbols which, treated mathematically, lead to some remarkable conclusions. For instance, chlorine, bromine, iodine, nitrogen, and phosphorus become compounds of hydrogen with as many unknown or "ideal" elements, which no actual analysis has yet identified. That is, the known phenomena of chemistry seem to be less simply interpreted by Brodie's calculus than in our commonly accepted theories, and certain classes of phenomena are not considered at all. It is true that Brodie never completed his work, but it is not easy to see how his notation and

[a] Phil Trans., 1866. A second part in 1877.

reasoning could have accounted for isomerism, much less for the facts which stereochemistry seeks to explain.

Just here we find the prime difficulty of all attempts to evade the atomic theory. Up to a certain point we can easily dispense with it, for we can start with the fact that every element has a definite combining number, and then, without any assumptions as to the ultimate meaning of these constants we can show that other constants are intimately connected with them. So far we can ignore the origin of the so-called atomic weight; but the moment we encounter the facts of isomerism or chemical structure, and of the partial substitution of one element by another, our troubles begin. The atomic theory connects all of these data together and gives the mind a simple reason for the relations which are observed. We can not be satisfied with mere equations; our thought will seek for that which lies behind them; and so the antitheorist fails to accomplish his purpose because he leaves the human mind out of account. The reasoning instrument has its own laws and requirements, and they, as well as the empirical observations of science, must be satisfied. Even in astronomy the law of gravitation is not enough; men are continually striving to ascertain its cause, and no number of failures can prevent them from trying again and yet again to penetrate into the heart of the mystery. In the atomic theory the same tendency is at work, and the very nature of the atom itself, that thing which we can neither see nor handle, has become a legitimate subject for our questionings. Shall we, having gone so far, assume that we can go no farther?

"All roads lead to Rome." If we accept the atomic theory, we sooner or later find ourselves speculating about the reality of the atom, and at last we come face to face with the old, old problem of the unity or diversity of matter. We can, if we choose, employ the theory as a working tool only and shut our ears to these profounder questions, but it is not easy to do so. What is the chemical atom? Is all matter ultimately one substance? We may be unable to solve either problem, and yet we can examine the evidence and see which way it points.

I think that all philosophical chemists are now of the belief that the elements are not absolutely distinct and separate entities. In favor of their elementary nature we have only negative evidence, the mere fact that with our present resources we are unable to decompose them into simpler forms. On that side of the argument there is nothing more. On the other hand, we see that the elements are bound together by the most intimate relations, so much so that unknown elements can be accurately described in advance of their discovery, and facts like these call for an explanation. Something belonging to the elements in common seems to underlie them all. If, however, we study the atomic weights, we are forced to observe that the elements do not

shade into one another continuously, but that they vary by leaps which are sometimes relatively large, and sometimes quite small. To Mendeléeff this irregular discontinuity is an argument against the unity of matter, or rather an indication that the periodic law lends no support to the belief; but such a conclusion is unnecessary. If the fundamental matter, the "protyle," as Crookes has called it, is itself discontinuous and atomic in structure, the same property must be shown in all of its aggregations, and so the difficulties seen by Mendeléeff disappear. The chemical atoms become clusters of smaller particles, whose relative magnitudes are as yet unknown.

That bodies smaller than atoms really exist is the conclusion reached by J. J. Thomson[a] from his researches upon the ionization of gases. According to him, this phenomenon "consists in the detachment from the atom of a negative ion," this being "the same for all gases." He regards "the atom as containing a large number of smaller bodies," which he calls "corpuscles," and these are equal to one another. "In the normal atom this assemblage of corpuscles forms a system which is electrically neutral." It must be borne in mind that these conclusions are drawn by Thomson from the study of one class of phenomena, and it is of course possible that they may not be finally sustained. Their value to us at the present moment lies in their suggestiveness and in the curious way in which they reenforce other arguments of similar purport. The possibility that the chemical atoms can be actually broken down into smaller particles of one and the same kind is, to say the least, startling, but it can not be disregarded. The evidence obtained by Thomson is, so far as it goes, positive, and it is entitled to receive due weight in all discussions of our present problem. It is the first direct testimony that we have been able to obtain, all previous evidence being either negative or circumstantial. It may be misinterpreted, but it is not to be pushed aside.

In direct line with the inferences of Thomson are the results obtained by Rutherford and Soddy in their researches upon radio-activity. Here, again, we have a subject so new that all opinions concerning it must be held open to revision, but, so far as we have yet gone, the evidence seems to point in one way. Rutherford and Soddy[b] have studied especially the emanations given off by thorium, and conclude that from this element a new body is continually generated in which the radio-activity steadily decays. This loss of emanative power is in some sort of equilibrium with the rate of its formation. When thorium is "de-emanated," it slowly regains its emanative power. The emanation is a "chemically inert gas, analogous in nature to the members of the argon family." The final conclusion is that radio-activity may be "considered as a manifestation of subatomic chemical change."

[a] Phil. Mag. (5), 48, p. 547. Also Popular Science Monthly, August, 1901.
[b] Phil. Mag. (6), 4, pp. 395, 581.

This word "subatomic" is one of ominous import. It implies atomic complexity, and it also suggests something more. The property of radio-activity is most strikingly exhibited by the metals radium, thorium, and uranium; and these have the highest atomic weights of any elements known. If the elements are complex, these are the most complex, and therefore, presumably, the most unstable. Are they in the act of breaking down? Is there a degradation of matter comparable with the dissipation of energy? We can ask these questions, but we may have to wait long for a reply. There is, however, another side to the shield, and the universe gives us glimpses of a generative process, an elementary evolution.

The truth or falsity of the nebular hypothesis is still an open question. It is a plausible hypothesis, however, and commands many strong arguments in its favor. We can see the nebulæ and prove them to be clouds of incandescent gas; we can trace a progressive development of suns and systems, and at the end of the series we have the habitable planet upon which we dwell. The nebular hypothesis accounts for the observed condition of things, and is therefore by most men regarded as satisfactory. But this is not all of the story. Chemically speaking, the nebulæ are exceedingly simple in composition; the whiter and hotter stars are a little more complex; then come stars like our sun, and finally the finished planets, with their many chemical elements and their myriads of compounds. Here again we have evidence bearing upon our problem, evidence which led me,[a] more than thirty years ago, to suggest that the evolution of planets from nebulæ had been accompanied by an evolution of the elements themselves. This thought, stated in a reversed form, has since been developed and amplified by Lockyer, and it is doubtless familiar to you all. In the development of the heavenly bodies we seem to see the growth of the elements; do we, in the phenomena of radio-activity, witness their decay? This is a startling, possibly a rash, speculation, but it rests upon evidence which must be considered and weighed.

We have, then, various lines of convergent testimony, and there are more which I might have cited, all pointing to the conclusion that the chemical atoms are complex, and that elemental matter, in the last analysis, is not of many kinds. That there is but one fundamental substance is not proved; and yet the probability in favor of such an assumption must be conceded. Assuming it to be true, what, then, is the nature of the Daltonian atom?

To the chemist the simplest answer to this question is that furnished by the researches of J. J. Thomson, to which reference has already been made. A cluster of smaller particles or corpuscles satisfies the conditions that chemistry imposes on the problem, their ultimate nature being left out of account. For chemical purposes we

[a] "Evolution and the spectroscope," Popular Science Monthly, January, 1873.

need not inquire whether the corpuscles are divisible or indivisible, although for other lines of investigation this question may be pertinent. But, no matter how far we may push our analysis, we must always see that something still lies beyond us and realize that nature has no assignable boundaries. That which philosophers call "the absolute" or "the unconditioned" is forever out of our reach.

Through many theories men have sought to get back a little farther. Among these Lord Kelvin's theory of vortex atoms is perhaps the most conspicuous and certainly the best known. It presupposes an ideal perfect fluid, continuous, homogeneous, and incompressible; portions of this in rotation form the vortex rings, which, when once set in motion by some creative power, move on indestructibly forever. These rings may be single or linked or knotted together, and they are the material atoms. The assumed permanence of the atom is thus accounted for and given at least a mathematical validity, but we have already seen that the chemical units may not be quite so simple. The ultimate corpuscles, to use J. J. Thomson's words, may be vortex rings; the chemical atom is much more complex. On this theory chemical union has been explained by supposing that vortices are assembled in rotation about one another, forming groups which are permanent under certain conditions and yet are capable of being broken down. The vortex ring is eternal; its groupings are transitory. This is a plausible and fascinating theory; if only we can imagine the ideal perfect fluid and apply to it the laws of motion; that done, all else follows. Unfortunately, however, the fundamental conception is difficult to grasp and still more difficult to apply. So far it has done little or nothing for chemistry; it has brought forth no discoveries nor stimulated chemical research; we can only say that it does not seem to be incompatible with what we think we know. In a certain way it unifies the two opposing conceptions of atomism and plenism, and this may be, after all, its chief merit.

But there are later theories than that of Kelvin, and some of them are most daring. For instance, Professor Larmor regards electricity as atomic in its nature, and supposes that there are two kinds of atoms—positive and negative electrons. These electrons are regarded as centers of strain in the ether, and matter is thought to consist of clusters of electrons in orbital motion round one another. Still more recently Prof. Osborne Reynolds, in his Rede lecture,[a] has offered us an even more startling solution of our problem. He replaces the conventional ether by a granular medium, generally homogeneous, closely packed, and having a density ten thousand times that of water. Here and there the medium is strained, producing what Reynolds calls "singular surfaces of misfit" between the normally piled grains and

[a] On an Inversion of Ideas as to the Structure of the Universe. Cambridge, 1903. The Rede lecture, delivered June 10, 1902.

their partially displaced neighbors. These surfaces are wave-like in character and constitute what we recognize as ordinary matter. Where they exist there is a local deficiency of mass, so that matter is less dense than its surroundings; and this, as Reynolds has said, is a complete inversion of the ideas which we now hold. Matter is measured by the absence of the mass which is needed to complete a normal piling of the grains in the medium. In other words, it might be defined as the defect of the universe. The "singular surfaces" already mentioned are molecules, which may cohere, but can not pass through one another, and they preserve their individuality.

Possibly I may misapprehend this theory, for it has been published in a most concise form, and the reasoning upon which it rests is not given in detail. I can not criticise it, but I may offer some suggestions. If matter consists of waves in a universal medium, how does chemical union take place? Shall we conceive of hydrogen as represented by one set of waves and nitrogen as represented by another, the two differing only in amplitude? If so, when they combine to form ammonia there should be either a superposition of one set upon the other, or else a complex system might be found showing interference phenomena. But would not the latter supposition imply a destruction of matter as matter is defined by the theory? Could one such wave coalesce with or neutralize another? To conceive of a union of waves without interference is not easy, but the facts of chemical combination must be taken into account. When we remember that compounds exist containing hundreds of atoms within the molecule, we begin to realize the difficulties which a complete theory of matter must overcome. Chemical and physical evidence must be taken together; neither can solve the problem alone. At present the simplest conception for the mind to grasp is that of an aggregation of particles. Beyond this all is confusion, and mathematical devices can help us only a little. In speaking thus I assign no limit to the revelations of the future; some theory, now before the world, may prove its right to existence and survive; but none such, as yet, can be taken as definitely established. The theory which stands the test of time will not be a figment of the imagination; it must be an expression of observed realties. But enough of speculation; let me, before I close, say a few words of a more practical character.

Dalton's statue stands in Manchester, a fitting tribute to his fame. But it is something which is finished; something on which no more can be done; something to be seen only by the few. As a local memorial it serves a worthy purpose, but Dalton's true monument is in the set of constants which he discovered, and which are in daily use by all chemists throughout the world. Here is something that is not finished; and here Dalton's memory can be still further honored, by good work, good research, honest efforts to increase our knowledge.

We have seen that the atomic weights are the fundamental constants of all exact chemistry, and that they are almost as important also to physics; but the mathematical law which must connect them is still unknown. Every discovery along the line of Dalton's theory is another stone added to his monument, and many such discoveries are yet to be made.

What, now, is needed? First, every atomic weight should be determined with the utmost accuracy, and what Stas did for a few elements ought to be done for all. This work has more than theoretical significance; its practical bearings are many, but it can not be done to the best advantage along established lines. So far the investigators have been a mob of individuals; they need to be organized into an army.

Collective work, cooperative research, is now demanded, and the men who have hitherto toiled separately should learn to pull together. Ten men, working on a common plan, in touch with one another, can accomplish more in a given time than a hundred solitaries. The principles at issue are well understood; the methods of research are well established; but the organizing power has not yet appeared. Shall this be a great institution for research, able to take up the problems which are too large for individuals to handle, or a voluntary cooperation between men who are unselfishly inclined to attempt the work? This question I can not answer; doubtless it will solve itself in time; but I am sure that a method of collective investigation will be found sooner or later, and that then the advance of exact knowledge will be more rapid than ever before. When the atomic weights are all accurately known, the problem of the nature of the elements will be near its solution. Some of the wealth which chemistry has created might well be expended for this purpose. Who will establish a Dalton laboratory for research, and so give the work which he started a permanent home?

INTRA-ATOMIC ENERGY.[a]

By Gustave Le Bon.

Section 1.—*Purpose of this paper.*

In 1902 we published a paper on the dissociation of matter, in which were detailed the results of certain experiments. Continuing the investigations on this subject, pursued for some years past, we resumed our experiments, and these have finally shown that the phenomenon of radio-activity, that is to say, the dissociation of atoms, at first supposed to be peculiar to certain exceptional bodies, such as uranium and radium, is, on the contrary, a general property of matter, and consequently one of the most widely diffused phenomena of nature.

The aptitude of bodies to become disaggregated, emitting effluvia analogous to the cathodic rays, and, like them, capable of traversing material substances and generating X rays, is universal. Light impinging upon any substance whatever, the burning of a lamp, chemical reactions of very diverse characters, an electric discharge, etc., may cause these effluvia. The bodies designated as radio-active substances, such as radium, only show in a higher degree a phenomenon which all matter possesses in some degree.

Section 2.—*Phenomena observed during the dissociation of matter.*

The radio-activity of matter, its dissociation, is always manifested by the emission into space of effluvia having a velocity comparable to that of light and possessing qualities analogous to those of cathodic rays, notably the quality of producing X rays as soon as they encounter an obstacle.

Numerous experiments have definitely shown the source of the various radio-active emissions. Whether they come from the cathode of a Crookes tube, from the radiation of a metal under the action of light, or from the radiation of bodies spontaneously radio-active, such as uranium, thorium, etc., these effluvia are of the same nature. They undergo the same magnetic deflection; the relation $\frac{e}{m}$ of their charge to their mass is the same. Their velocity alone varies, but is always very great.

[a] Translated and condensed from the Revue Scientifique, 4th series, Vol. XX, Nos. 16, 17, and 18.

The cathodic rays are charged with electricity, yet can traverse thin metallic plates connected with the earth without losing their charge. Whenever they impinge upon an obstacle they immediately give rise to those peculiar radiations called X rays, which differ from the cathodic rays in that they are not deflected by a magnet and traverse thick metallic plates capable of averting those rays.

Cathodic rays and X rays produce electricity upon all bodies, whether gaseous or solid, which they meet. They consequently render the air a conductor of electricity.

By measuring the deflection of the cathodic rays by an electric field and by a magnetic field, we may estimate the velocity of the particles composing them, and the relation $\frac{e}{m}$ of their charge e to their mass m. The velocity found equals a third of that of light. If m expresses the electric charge in coulombs, we obtain 10^8 for the relation $\frac{e}{m}$.[a]

In electrolysis the relation for hydrogen is 10^5, one thousand times smaller. The charge e being the same, the mass of the cathodic particle would be one one-thousandth that of the atom of hydrogen, the smallest of known atoms. The ordinary atom would then be dissociated into 1,000 parts to form the cathodic particle.

In place of a Crookes tube let us now use a substance spontaneously very radio-active—thorium or radium, for example. We again find most of the preceding phenomena with simple quantitative variations. For example, we find more rays charged with negative electricity in the Crookes tubes than in the radium emanations which are specially charged with positive electricity; but the nature of the phenomena observed in the two cases appears to be identical.

Radio-active bodies emit three different kinds of radiation, which may be designated by the letters α, β, and γ.

The α radiations are but slightly penetrating, are charged with positive electricity, and form the greatest part of the emitted rays. It is under their influence that the air becomes a conductor of electricity. They appear to be formed by the projection of particles about the size of a hydrogen atom that is to say, one thousand times greater than the particles of the β radiations; their velocity is about one-tenth that of light. They can not be deflected except by a very powerful magnet.

The β radiations are similar in all respects to the cathodic rays of a Crookes tube. Like them they are charged with negative electricity,

[a] This relation varies according to different observers between 1.55 by 10^7 and 1.84 by 10^7 (in electro-magnetic units). If we adopt the latter figure we see that it represents the enormous charge of 184 millions of coulombs per gramme of cathodic matter. In electrolysis the charge of a gramme of hydrogen amounts to only 96,000 coulombs.

and may also be deflected by a magnet, but in the opposite direction from that taken by the α radiations. They are the ones that produce the photographic effects. They must be very penetrating.[a] Their velocity, according to Kaufmann, must be nearly that of light.

The γ radiations are not deflected by a magnetic field and are probably similar to X rays and, like them, very penetrating. Their velocity, according to Blondlot, must be exactly that of light; that is to say, 300,000 kilometers per second.

Besides these various kinds of radiations which have, as we shall see in a future paragraph, none of the properties of matter, radio-active bodies emit, in an infinitely small quantity, an emanation having the character of a gas, which can be condensed by means of liquid air at a temperature of -150° and is made up, according to Ramsay, of helium. It gives to bodies with which it comes in contact a temporary radio-activity. The product of the condensation, whose properties are shown by the action of the electrometer, is invisible and imponderable, but it can be dissolved in certain acids, and on evaporating the solution the radio-activity is obtained, unchanged, in the residue.

The effluvia of radio-active bodies have very active physiological properties that have already been studied by many observers. Concentrated radium, even when incased by a metallic envelope, burns the skin. It paralyzes bacteria.

Induced radio-activity, discovered by Rutherford, is that phenomenon by virtue of which radio-active bodies, especially in solution, communicate for some time their radio-activity to surrounding bodies, either insulating or conducting. It seems quite evident that in this case we are dealing with material substances, since induced radio-activity is not effected through glass and mica, and may be carried to a distance from radio-active bodies. On blowing the disengaged particles through a coiled tube and projecting them upon any body whatever, the latter soon acquires a temporary radio-activity.

It is by induced radio-activity that is produced the phosphorescence of sulphide of zinc inclosed in a glass receiver communicating by a large tube with another receiver containing a solution of radium. Bismuth plunged for some days in a solution of nitrate of radium finally, for the same reason, becomes phosphorescent. All radio-active bodies are more active in solution than in a solid state, but then they lose their phosphorescence and can only induce it by their emanations.

[a] In this, as Rutherford says, they do not resemble the cathodic rays, since the latter, as Lenard has shown, will hardly traverse metallic layers no thicker than one one-hundredth of a millimeter. It is probable, rather, that the penetration of metals is due to the X rays that always accompany these radiations or that are at least always engendered by them.

It seems probable that the property possessed by radio-active emanations of condensing the vapor of water is due to material particles carried along by their radiating force, especially if we consider these particles as electrified. This is a property common to all dusts, as can be easily shown by the following well-known experiment: A glass receiver containing water in a state of ebullition communicates, by glass tubes, with two other receivers, one filled with ordinary air taken from the room, the other with air deprived of its dust by simple filtration through cotton wool. The water vapor entering the receiver containing the dust-laden air immediately condenses into a thick fog, while that entering the other receiver remains transparent.

SECTION 3.—*Intra-atomic forces as a special form of energy.*

When radio-active bodies were discovered physicists did not take the pains to measure the amount of energy liberated during their dissociation, but vainly sought and still continue to seek some external source from which these bodies might derive that energy. It is, in fact, considered as an absolutely fundamental principle that matter can only give back in some form or other energy it has previously received.

Now, since all physicists are to-day unanimous in affirming that the products of all kinds of radio-activity are similar; and since, on the other hand, the energy necessary for the emitting into space effluvia having the velocity that the radio-active particles possess is immensely superior to that we are able to produce by the various forces at our disposal, is it not evident that it is not outside of matter but within matter itself that we must seek for the source of the energy expended? This liberated energy is the consequence of intra-atomic reactions which we shall shortly consider and which differ essentially from the extra-atomic reactions that come under the domain of chemistry, even if in no other way, by the enormous magnitude of the effects produced.

If this is so—and it is not possible to conceive that it should be otherwise—we are immediately led to look upon the atoms that make up matter as immense reservoirs of energy. They may manifest this energy without borrowing from without, since it exists within themselves where it was accumulated at the time of their formation.

What are the fundamental characteristics of this hitherto ignored energy which we may call simply intra-atomic energy?

It differs from all others with which we are acquainted by its prodigious power. If, instead of dissociating only a few millionths of a milligram of matter, as we do now, we could succeed in dissociating some kilograms, we would have, as we shall show, a source of energy compared with which all the motors combined now driven by coal would present an insignificant total. It is because of the amount of

this energy that the radio-active phenomena show such intensity. It is this which causes the emission of particles endowed with an immense velocity, phosphorescence and the production of an enormous quantity of electricity, out of proportion to that which we can maintain upon insulated bodies.

The great velocity of the particles discharged into space under the influence of the energy liberated in the atom would be of itself a proof that we are in the presence of an entirely new force. It is only in vibrations of the ether that a velocity comparable to this has hitherto been observed, and there we readily explain it by the almost perfect elasticity of the medium. No analogous explanation can be invoked for the projections of the particles.

X rays also are one of the indirect manifestations of intra-atomic energy, a new stage of its manifestation.

A form of energy may be declared new when it is differentiated by its fundamental characters from all those previously known.

We do not yet know all the possible transformations of this new mode of energy, but we are already convinced as to its origin. We know that it comes from matter, since we can not produce it without matter. We know also that when it is once formed it is no longer matter, since it has lost all material characters, and that it can not again become matter by any process.

Before an assemblage of facts as conclusive and clear as these, it seems impossible to admit any hypothesis other than this: Here is an entirely new mode of energy having no relation to any of those hitherto observed.

The origin of intra-atomic energy is not entirely inexplicable if we admit, with astronomers, that the condensation of a nebula sufficed, by itself alone, to produce the considerable temperature possessed by the sun. It may be conceived that an analogous condensation of the ether may have generated the energies contained in the atom. We may roughly compare the latter to a sphere in which a nonliquefiable gas was compressed by some billions of atmospheres at the time of the origin of the world.

SECTION 4.—*Power of the intra-atomic forces—Matter considered as an enormous condensation of energy.*

GREAT AMOUNT OF INTRA-ATOMIC ENERGY.

The great energy manifested in radio-active phenomena has profoundly impressed physicists, and for a long time past they have been seeking its origin. One of them recently observed that the complete dissociation of a gram of radium would produce sufficient energy to transport the entire English fleet to the summit of Mont Blanc.

Let us try to state with some exactitude the amount of force condensed in a small quantity of any matter whatever. The various methods employed for measuring the velocity of the radio-active particles have always given about the same results. This velocity is nearly that of light for certain radio-active emissions and about one-third of that for the particles in a Crookes tube. Let us take the lowest of these velocities—about 100,000 kilometers per second—and try, by taking this for a base, to calculate the energy that would be required to completely dissociate one gram of any matter whatever.

The work performed by a body in motion being equal to half the product of its mass with the square of its velocity, an elementary calculation gives at once the power which would be manifested by the particles of this gram of matter in case they were endowed with the supposed velocity. It would be equal to about 6,800,000 horse-power. This amount of energy would suffice to move, on a level road, a freight train having a length of a little more than four and one-fourth times the circumference of the globe.

To move such a train by means of coal would require 2,830,000 kilograms, which, at 24 francs a ton, would cost about 68,000 francs.

These figures, so vast as at first to seem improbable, depend upon the enormous velocity by which the particles are impelled, a velocity which we can not approach by any known mechanical means. In the factor mV^2 the mass of 1 gram is certainly very small; but as its velocity is immense, the effects produced must likewise be immense.

Now, all the velocities which we can produce are almost as nothing compared with those of the particles of dissociated matter. We can scarcely exceed 1 kilometer per second by the means at our disposal, while the velocity of the radio-active particles is 100,000 times greater. Hence the tremendous effects produced.

Rutherford has said that the energy manifested in radio-active phenomena is "perhaps a million times greater than that produced by the various known reactions of molecular forces."

He also remarks—and he is, as far as I know, the first physicist who has decided to make such a statement—that "since the radio-active elements do not differ from the other chemical elements by any of their chemical characters, there is no reason to think that the enormous reserve of energy they possess is peculiar to them alone. It seems probable, then, that atomic energy is general and of equal force in all bodies."[a] This is the thesis that I have constantly defended and upon which I have for a long time based my contention concerning the existence of a new form of energy surpassing in force all we have hitherto known.

Shall we some day succeed in easily liberating this colossal force that lies within the atoms? No one can tell. Neither could one have

[a] Philosophical Magazine, May, 1903, p. 590.

told in the time of Galvani that the energy which was used with difficulty to twitch the legs of a frog and attract small fragments of paper would one day set in motion enormous railway trains.

Perhaps it will always be beyond our powers to completely dissociate the atom, because the difficulty would probably increase as dissociation advances, yet to dissociate a very small part would suffice.

If, as physicists still claim, matter, instead of being an immense reservoir of energy, can only restore the energy communicated to it by some means or other—heat, for example—it is evident that in order to produce the dissociation of matter there would be necessary an expenditure of work exactly equal to that which the results of the dissociation would perform, conformably to one of the fundamental principles of thermo-dynamics.

It can not, however, be longer held that the energy exhibited by the dissociated atom comes from without; it must be borrowed from the enormous reserve that it possesses. Besides, even if it were merely an agent in the transformation of energy, the importance of dissociation would still remain, since we can produce it by agents that are to-day absolutely free to all and unutilized, such as light.[a]

MATTER CONSIDERED AS AN ENORMOUS CONDENSATION OF ENERGY.

The indisputable fact that the atom is a reservoir of energy leads immediately, in my opinion, to the hypothesis that matter is composed only of condensed energy of a special mode, whence result its weight, its form, and its fixity. It is to energy thus considered that we give the name of matter.

Some ancient facts, quite anterior to the discovery of the cathodic rays, already pointed to this idea. Take, for example, the quantity of electricity extracted from bodies by electrolysis. A gram of a substance such as hydrogen contains a charge of 96,000 coulombs. The electricity must be there in a state of very considerable condensation, since by no means at our disposal can we make an insulated body of the size we have mentioned hold more than a very small fraction of this charge. Joubert has observed that the quantity of electricity contained in a cubic centimeter of hydrogen would suffice to charge a sphere as large as the earth with a potential of 6,000 volts.

In my opinion electricity is only one of the manifestations of special energy contained in the atoms. It is the state of prodigious condensation of this energy that permits the generation of the enormous

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[a] In a recent work (On ether and gravitational matter through infinite space) Lord Kelvin expresses himself as follows: "The mechanical value of a cubic kilometer of solar light is equal to 412 kilogram meters, equivalent to the work of a horsepower for five and one-half seconds. This result may give some idea of the actual total of the mechanical energy of the luminous vibrations and of the forces contained in our atmosphere."

quantity of electricity that the atom can produce, only a part of which, very probably, appears in ordinary electrolysis. This is not an hypothesis, since, in the radio-activity manifested by simple bodies, the quantity of electricity liberated for a given weight of matter is considerably larger than in electrolysis.

In all the ordinary operations to which we submit matter—fusion, vaporization, etc., and in all chemical operations—we communicate to it an additional amount of energy, which apparently augments the movements of rotation or vibration of the atoms, but we do not touch their structure, and that is why matter so easily resumes its primitive state, as we see it do, for example, when we allow a liquefied body to cool.

SECTION 5.—*The transition between the ponderable and the imponderable.*

Current ideas as to the distinction between the ponderable and the imponderable. Science formerly classified the various phenomena of nature by placing them in clearly separated groups, between which there appeared to be no connection. These distinctions existed in all branches of knowledge.

The discovery of the laws of evolution occasioned the disappearance from the natural sciences of the divisions that had previously seemed insuperable barriers, and from the protoplasm of primitive creatures up to man the chain is to-day almost uninterrupted. Missing links are restored every day, and we now see how changes have been effected in the course of time from the most simple to the most complex beings.

Physics has followed a similar road, but all the chasms that separate its different branches have not yet been spanned. It has slowly got rid of the fluids that formerly embarrassed it. It has discovered the relations between the different forces and now admits that they all are but varied manifestations of something indestructible—energy. Thus it has established the serial permanence of phenomena, has shown the existence of continuity where only discontinuity formerly appeared. The law of the conservation of energy is in reality only a simple statement of this continuity. In order to establish continuity throughout, physics has still an enormous step to take. It still maintains that there is a deep gulf between the ponderable and the imponderable; that energy and matter are sharply separated, matter and ether no less so.

In the present state of scientific thought two ideas are current that should be considered apart; first, matter can not itself create energy; second, the imponderable ether is entirely distinct from ponderable matter—that is to say, it has no analogy with it.

The foundations on which these ideas were established seemed to be so solid that they would defy the inroads of time. We shall, however, endeavor to show that new facts tend to successfully undermine them.

The transformation of matter into energy.—A material system isolated from all external action can not spontaneously generate energy. If we suppose it to be endowed with an internal energy, chemical or otherwise, its quantity of energy will remain invariable as long as the system is subject only to internal action. This is one of the great principles of thermo-dynamics.

All past scientific observations seemed to entirely confirm this idea, that no substance can produce energy without having first borrowed it from without. All thermo-chemistry is based on the principle that "the heat disengaged or absorbed in the decomposition of a body is exactly equal, and contrary in sign to that which it has been necessary to employ for its transformation."

To cause the disappearance of this sharp separation we have just noted it is necessary to succeed in transforming matter into energy without furnishing anything from without. Now it is just this spontaneous transformation that is shown us by all the experiments I have cited on the radio-activity of matter. The spontaneous production of energy thus shown, so at variance with current scientific ideas, has much embarrassed physicists, who have tried in vain to discover, outside of the matter affected, the origin of the energy manifested by it. We have seen that the explanation becomes very simple as soon as we consent to admit, in accordance with the clearest evidence, that matter contains a reserve of energy which it can partially lose, either spontaneously or under slight exciting influences. It may doubtless be said that it is not really matter that is transformed into energy, but merely an intra-atomic energy that is given out. Yet, as this energy of intra-atomic origin can not be generated without the final disappearance of matter, we are justified in saying that this is just what would happen if matter were transformed into energy. To state this more fully it would first be necessary to understand the intimate nature of matter and energy, which no one thus far has been able to do.

The transition between the ponderable and the imponderable—Properties of the substance intermediate between matter and ether.—We have now reached the second of the propositions above enunciated as one of the great scientific dogmas of the present day, namely, that the ponderable and the imponderable, that is to say, matter and ether, are absolutely distinct, and that there is no connection between them.

In order to prove that this is not the case, we must show that the effluvia generated by all bodies during their dissociation consist of a substance having characters intermediate between those of ether and those of matter.

During many years physicists have held that the particles emitted in the phenomena of radio-activity were merely fragments of atoms, doubtless charged with electricity, but nevertheless always formed of matter.

This opinion might seem to be confirmed by the fact that radio-active emissions are often accompanied by a projection of material particles. In a Crookes tube the emission of solid particles from the cathode is so considerable that they metallize plates exposed to their projection.

Similar deportation of matter is likewise observed in most electric phenomena, notably when electricity having a sufficiently high potential passes between two electrodes. The spectrum of the electric sparks then formed always shows the lines characteristic of the metals of which the electrodes are formed. After repeated discharges between a ball of gold and one of silver, we find silver on the gold ball and gold on the silver one. With currents of high frequency Monsieur Oudin showed that electrodes of amalgamated gold, used in air having the ordinary pressure, lose nearly one-tenth of a milligram of their weight per hour. In these various cases matter is doubtless carried away by the velocity of the electric molecules, as is the sand of the sea by the violence of the waves.

Still another reason seemed to clearly prove the materiality of the cathodic emissions. They can be deflected by the magnetic field; besides, they are charged with electricity, and as electricity had not been known to be transported without material support it was necessary to presuppose the existence of such a support. It is true that, in the theory of electrons, it is admitted that the electric atom in motion, wholly free from all matter, behaves exactly like a current and can be deflected by a magnet; but some years ago that theory, unsupported by the discovery since made by Zeemann, had not the considerable extension it has to-day.

The kind of matter-dust supposed to form the emissions from the cathode and from radio-active bodies showed very singular characteristics for a material substance. According to the experiments of J. J. Thomson, the products of this emission were identical, no matter what might be the body dissociated. The electric charge and the mass being always the same, it was necessary to admit that in different bodies identical elements were found.

These supposed material elements had likewise lost all the properties of the matter that gave them birth. Lenard showed this clearly when he sought to verify one of the ancient hypotheses, according to which the effluvia generated by ultra-violet light impinging upon metals are composed of dust torn from the surface of metals. Taking a body—sodium—easily dissociated by light, and which can also be detected in infinitesimal quantities in air by means of the spectroscope, he found

that the products of dissociation showed no trace of sodium. If, then, the effluvia of radio-active bodies are matter, such matter possesses none of the properties of that from which it was derived.

Max Abraham and Kaufmann proved that the dissociated atoms of radio-active phenomena are transformed into something extremely different from matter, and which they consider to be composed exclusively of atoms of electricity; that is to say, of what one to-day calls electrons, bodies without weight, which differ essentially from ordinary matter, having no character in common with it except a certain amount of inertia.

Inertia is, as is well known, the resistance, whose cause is unknown, that bodies oppose to movement or change of movement. It can be measured and its measure is defined by the term "mass." Mass, then, is the measure of the inertia of matter, its coefficient of resistance to movement. It has an invariable value for every material body, one which remains invariable throughout all the transformations to which that body may be subjected. Constancy of mass is, as I mentioned above, one of the fundamental principles of mechanics and of chemistry.

Now, this property possessed by the material atom is also possessed by the electric atom to a certain degree. For some years it has been admitted that electricity is endowed with inertia. It is, indeed, by means of this property that we explain the phenomena of induction and of oscillating discharges. We are ignorant whether that inertia has the same unit of measure as the inertia of matter. Some physicists suppose, without, indeed, being able to offer any proof, that the inertia of matter is due to the electrons and is entirely of electro-magnetic origin.

It does not seem, however, that we can identify the inertia of matter with that of the electric atom whose mass is, in reality, only an apparent mass, resulting simply from its state of an electrified body in movement. The electric corpuscle seems to have a longitudinal mass (measured by opposition to acceleration in the direction of motion) different from its transversal mass (perpendicular to the direction of motion). It is clear that the properties of an electric atom differ considerably from those of a material atom.

What, then, is the constitution of these hypothetical electric atoms emitted by all bodies during radio-activity?

The answer to that question will furnish us with exactly the link between the ponderable and the imponderable, for which we are searching.

It is evidently impossible, in the present state of our knowledge, to define an electric atom, but we can at least characterize it thus: A substance that is neither a solid, a liquid, nor a gas, that has no weight, that traverses obstacles without difficulty, and that has no

property in common with matter, except a certain inertia, and, what is more, an inertia varying with the velocity, that is more like ether than matter and forms a transition between them.

The formation of effluvia is an incontestable testimony to the transformation of the ponderable into the imponderable.

This transformation, so contrary to all the precepts laid down by science, is nevertheless one of the most frequent phenomena in nature. It is daily effected under our eyes, but as we formerly possessed no reagent for testing it it was unobserved.

SECTION 6.—*The current conception as to atoms.*

Origin of current ideas concerning the structure of atoms.—Those scientists who follow in foreign journals the experiments and discussions of the most eminent physicists of the present day, such as Lord Kelvin, J. J. Thomson, Crookes, Larmor, Lorentz, and many others, have before them a curious spectacle. They see melting away before them, day by day, fundamental scientific conceptions that seemed established solidly enough to remain forever.

Being unable to give, in detail, the steps of this evolution, I will confine myself to stating summarily the researches of which the present theories seem the necessary consequence.

Five fundamental discoveries were the origin of the transformation of ideas concerning matter and electricity. These were, first, facts revealed by the study of electrolytic dissociation; second, the discovery of the cathodic rays; third, that of the X-rays; fourth, that of the so-called radio-active bodies, such as uranium and radium; fifth, the demonstration that radio-activity is not a peculiar property of certain bodies, but is a general property of matter.

The oldest of these discoveries, since, indeed, it goes back to Davy—that is to say, to the commencement of the last century—is that of the dissociation of chemical compounds by an electrical current. Its study was completed later by various physicists, notably by Faraday, and, in our time, by Arrhenius. It led on toward the theory of atomic electricity and the preponderating influence which electric atoms or electrons have in chemical reactions and the properties of bodies.

It seemed formerly that electric dissociation could only be obtained from compound bodies, never with simple ones. Yet, as soon as the cathodic rays and radio-activity were discovered, the theory of electric dissociation seemed to explain them very well on the simple condition of admitting that the atoms of a simple body contain, like those of a compound body, electric atoms having contrary signs and susceptible, like them, of separation.

The second of these discoveries, that of the cathodic rays, suggested the idea that there might be a state of matter different from any hitherto known; but this idea remained without influence up to the

day when Röntgen, examining more closely the Crookes tubes which physicists had been using for more than twenty years without seeing anything new in them, discovered that they gave out peculiar rays, absolutely different from any then known, to which he gave the name of X-rays. By this discovery a quite unforeseen thing, entirely new, since it found no analogy of any kind in known phenomena, was placed before the world of science.

The discovery of the radio-activity of uranium followed closely upon that of the X-rays, and had the consequences which I have already stated. It led especially to the admission that the atoms of certain bodies, supposed at first to be exceptional in character, possess the extraordinary property of dissociating themselves, but, as I showed that this property belongs to all bodies, it was necessary to recognize that there exists in matter a special and universal property totally unknown hitherto, and from which it results that the structure of the atom is necessarily very different from that which had for a long time been supposed.

Present ideas as to the structure of atoms.—The first origin of our present ideas concerning the structure of atoms was a consequence of Faraday's discoveries in electrolysis. He proved that the molecules of compound bodies carry a charge of neutral electricity, definite and constant in amount, which becomes dissociated into positive ions and negative ions when solutions of metallic salts are traversed by an electric current. The atom was soon considered as composed of two elements, a material particle and an electric charge which was believed to be combined with it or superposed upon it.

In this phase of the evolution of ideas the positive electron and the negative electron are merely two substances to be added to the list of elementary bodies with which they are capable of combining. The idea of the material atom still persists.

In the present evolution there is a tendency to go much further. After asking themselves whether this material support of the electron was really necessary, many physicists have reached the conclusion that it is not. They reject it entirely and consider the atom as wholly constituted of an aggregate of electrical corpuscles without any material support. The structure of matter would then be exclusively electrical.

This is evidently a considerable step, and by no means all physicists have yet taken it. Classical ideas prepossess our minds too completely to be easily got rid of; but, judging from the general tendency at the present time, it would seem quite possible that this idea may itself become classical in its turn.

As soon as the material atom is generally considered as a simple aggregation of electric corpuscles we are very quickly led to admit that it is only a condensation of energy.

According to the partisans of the exclusively electric structure of matter, the atom is entirely made up of a certain number of electric vortices. Around a small number of positive electrons there whirl, with dizzy velocity, the negative electrons to the number of a thousand, and often more.

Taken together they form an atom, which is thus a sort of solar system in miniature. "The material atom," says Larmor, "is composed of electrons, and of nothing else."

These electrons, by neutralizing each other, render the atom electrically neutral. The latter becomes positive or negative only when it is deprived of electrons of corresponding contrary signs, as is done in electrolysis. All chemical reactions are due to losses or gains in electrons.

It will be seen that the old atom of the chemists, formerly considered so simple, is really remarkably complex. It is a veritable siderial system, comprising a sun and planets that gravitate about it. From the architecture of this system are derived the properties of the various atoms, but all have the same fundamental elements.

SECTION 7.—*Ether the fundamental substance of atoms.*

The greater part of the phenomena studied by physics—light, heat, radiant electricity, etc.—are considered as produced by vibrations of the ether. Gravitation, from which we derive a knowledge of celestial mechanics and the course of the stars, seems to be still another of its manifestations. The theoretical speculations on the constitution of atoms seem also to demand the ether for a basis.

The necessity for the ether has long been realized, because no phenomenon would be conceivable without the existence of this medium. Without it there would probably be neither weight, nor light, nor electricity, nor heat—in a word, nothing of that with which we are acquainted. The universe would be silent and dead, or would manifest itself in a form utterly inconceivable. If we could construct a chamber of glass from which the ether was entirely removed, neither heat nor light could traverse it. It would be absolutely black, and probably gravitation would cease to act upon bodies placed within it. They would then lose all their weight.

Yet, as soon as we attempt to define the properties of the ether, enormous difficulties appear. They arise, especially, from the fact that, being unable to connect it with anything known, terms of comparison, and consequently of definition, fail entirely.

When the books on physics say, in a few lines, that the ether is an imponderable medium that fills the universe, the first idea that comes into the mind represents it as a kind of gas sufficiently rarefied to be imponderable by the means at our disposal. It is not difficult to imagine such a gas. A. Müller has calculated that if we should diffuse

the matter of the sun and the planets that surround it throughout a space equal to that which separates us from the nearest fixed stars, a cubic myriameter of such matter thus diffused into a gaseous state would scarcely weigh the millionth of a milligram, and would consequently be imponderable in our balances. A gas of such tenuity, representing perhaps the primitive state of our nebula, would be a quadrillion times less dense than the vacuum carried to the millionth of an atmosphere in a Crookes tube.

Unhappily the constitution of the ether can not be compared in any way with that of a gas. Gases are very compressible, while ether can not be notably compressed. If it were, it could not transmit almost instantaneously the vibrations of light.

It is only in fluids theoretically perfect, or, better yet, in solids, that we can find distant analogies with the ether; but we must then imagine a substance having very singular properties. It must have a rigidity surpassing that of steel, for if it did not possess that it would not transmit luminous vibrations at a speed of 300,000 kilometers per second. The most illustrious of our modern physicists, Lord Kelvin, considers ether as "an elastic solid filling all space."

The elastic solid that forms the ether has very strange properties for a solid, properties which we find in no other. Its extreme rigidity must be associated with an extraordinarily low density—that is to say, so low that its friction is unable to retard the motion of the stars in space. Hein has calculated that if the density of the ether were only a million times less than that of the air of a Crookes tube it would produce a secular alteration of half a second in the average motion of the moon. Such a medium, in spite of its greatly reduced density, would soon remove the atmosphere from the earth. It has been calculated that if it had the properties that we attribute to a gas it would acquire by its impact with the surface of planets deprived of atmosphere, like the moon, a temperature of 38,000°. Finally we reach the idea that the ether is a solid without density or weight, unintelligible as such a proposition may seem.

In order to explain the phenomena observed we must admit that in this subtance, more rigid than steel, bodies move freely, and we may produce in it, by setting on fire any substance whatever, those prodigiously rapid vibrations called light—vibrations of such velocity that if we compare them with the speed of a cannon ball the latter seems at rest. With a piece of glass cut in a certain manner we can deflect the luminiferous ether from its course and separate its vibrations. It is an agent that we encounter everywhere, that we set into vibration and deflect at will, but which we can never seize.

That which is still more astonishing is the magnitude of the forces which the ether is able to transmit. An electromagnet must act across a vacuum by the intermediation of the ether. Now, as Lord Kelvin

remarks, it acts upon iron at a distance with a force that may amount to 110 kilograms per square centimeter. "How is it," says the great physicist, "that these tremendous forces are developed within the ether and that nevertheless solid bodies are free to move through this solid?" We do not know and we can not tell whether we shall ever know. We do not know the actual relations existing between electricity and the ether, although it seems more and more evident that one is derived from the other.

Maxwell considers the ether "as composed of small spheres animated with a very rapid movement of rotation which they transmit from one to another." Fresnel regarded its elasticity as constant, but its density as variable. Other physicists believe, on the contrary, that its density is constant and its elasticity variable. Most of them think that it is not displaced by the movements of the material systems that traverse it, but passes through the interstices of all molecules as water passes through sand.

The physicists are, however, wholly agreed that the ether is a substance entirely different from matter and that it is not subject to the laws of gravitation. It is a substance without weight and immaterial in the usual sense of that word. It forms the world of the imponderable.

If the ether has no weight it must nevertheless have mass, since it presents resistance to movement. This mass is very slight, since the rapidity of the propagation of light is very great. If it were nothing at all, such propagation would be instantaneous.

The question of the imponderability of ether, which was discussed for a long time, seems now definitely settled. It was quite recently taken up by Lord Kelvin,[a] and, for mathematical reasons, which I can not detail here, he arrives at the conclusion that the ether is formed by a substance in no way under the control of the laws of gravitation—that is to say, imponderable. "But," adds he, "we have no reason to consider it as absolutely incompressible, and we may admit that a sufficient pressure might condense it."

It is probable that from this condensation, effected at the beginning of time by a mechanism of which we are entirely ignorant, are derived the atoms which are considered by many physicists, notably Larmor, as nuclei of condensation in the ether having the form of little vortices endowed with an enormous rotatory velocity. "The material molecule," writes this physicist, "is formed entirely by the ether, and by nothing else."[b]

It is difficult to believe that with such properties the ether is homogeneous. If it had been so, the worlds could not have been formed.

[a] On the clustering of gravitational matter in any part of the universe. (Philosophical Magazine, Jan., 1902.)

[b] Ether and Matter. 8vo. 400 pages. London, 1900. The work treats, however, of ether and matter from a mathematical point of view only.

SECTION 8.—*Intra-atomic chemical reactions producing the dissociation of matter.*

In examining the properties of radio-active bodies we reached the conclusion that the radiations they produce come solely from the energy furnished by the atom where it is found in a state of enormous condensation. The radiating particles would then be a product of a disintegration effected in the very interior of the atom.

This disintegration, however, necessarily implies a change of equilibrium in the arrangement of the numerous elements that compose an atom. Evidently it is only by passing to other forms of equilibrium that it can lose its energy, and consequently cause radiations.

The variations of which it is, then, the seat, differ from those with which chemistry is acquainted by this fundamental particular, that they are intra-atomic, while the ordinary reactions affecting only the architecture of groups of atoms are extra-atomic. Ordinary chemistry can only vary the arrangement of the stones that form an edifice. In the dissociation of atoms the materials of which the edifice is constructed are themselves changed.

We are ignorant of the mechanism by which this atomic disaggregation is effected, but it is quite clear that it implies conditions of a special kind necessarily very different from those hitherto studied by chemistry. The quantities of matter involved are infinitely small and the energy liberated is extraordinarily great, which is the opposite of what occurs in our ordinary reactions.

We have always maintained[a] that there is an analogy between the phenomena observed and those peculiar chemical reactions that produce phosphorescence. These reactions take place between bodies of which one, in infinitesimal proportions to the other, probably acts by commencing a dissociation. Sulphate of quinine, for example, is not radio-active. By allowing it to become hydrated after desiccation it shows radio-activity as long as the hydration lasts. Mercury and tin present but slight traces of radio-activity under the influence of light, but by adding to the first of these bodies a small portion of the second its radio-activity soon becomes very intense.[b]

[a] See especially Comptes rendus de l'Académie des Sciences, April, 1900, p. 892, and Revue Scientifique, April, 1900, p. 452.

[b] *La variabilité des espèces chimiques* (Revue Scientifique, December 22, 1900). In the bulbs of incandescent lamps it is noted that the incandescence is no longer produced if the proportion of oxide of cerium added to the oxide of thorium is less than 1 per cent. Armstrong and Auer admit that the incandescence is due to an oscillatory oxidation—that is to say, one that is alternately produced and extinguished. When oxidated the cerium might combine with thorium, when there would soon be decomposition, then reoxidation and combination, and so on. These reactions, produced millions of times a second, occasion the luminous oscillations of the ether which produce incandescence. The theory is very much open to discussion, and I reproduce it here only to show that the idea of reactions that are set up and discontinued millions of times a second, and consequently very different from all those known, seems very acceptable to eminent chemists.

The idea that radio-activity originates in a peculiar chemical process has rallied to its support several eminent physicists. Notably, it has been adopted and defended by Rutherford.

"Radio-activity," says he, "is due to a succession of chemical changes in which new types of radio-active matter are continually formed. It is a process of equilibrium in which the cost of the production of new radio-activity is balanced by the loss of the radio-activity already produced. The radio-activity is maintained by the continual production of new quantities of matter possessing temporary radio-activity.

"A radio-active body is, for that very reason, one which is being transformed. Radio-activity is the expression of its incessant loss. Its change is necessarily an atomic disaggregation. The atoms which have lost something are, by that fact alone, new atoms."[a]

Although the quantity of energy radiated by the atoms that are undergoing a commencement of disaggregation may be relatively very great, the loss of material substance that occurs in these reactions is very slight, precisely because of the enormous condensation of energy that is contained in the atom. Professor Becquerel has estimated that 1 gram of radium loses 1 milligram of matter in a thousand millions of years. Professor Curie contents himself with one million years. Still more modest, Professor Rutherford speaks only of some thousands of years, and Professor Crookes of hundreds of years. These figures, the first of which are quite fantastic, are reduced more and more as more accurate experiments are made.

According to certain experiments of my own, 1 gram would last one hundred years, which is just the figure given by Professor Crookes. The matter can only be absolutely settled by repeated experiments.

Yet even if we accept the figure that Professor Rutherford gives of some thousands of years for the duration of 1 gram of radium, it would suffice to prove that if uranium, thorium, and radium had existed with their radio-active properties in the geological epochs they would long ago have disappeared. This again supports our theory that rapid spontaneous radio-activity appeared only after the bodies became engaged in certain chemical combinations capable of affecting the stability of their atoms, combinations which we may succeed in reproducing.

What is the nature of these combinations? Of this we are yet ignorant, but the various examples cited in my preceding papers[b] prove that there exists a whole series of reactions (hydration of various substances, decomposition of water, decomposition of carbide of calcium, etc.), capable of causing atomic dissociation, and which

[a] Philosophical Magazine, February, 1903.

[b] Revue Scientifique, April, 1900, p. 892, and November 15, 1902, p. 621.

have not been taken into account by chemists because their balances, the most essential means for testing, are not sufficiently sensitive to show the changes that occur.

It is evident that we do not yet know the mechanism of the intra-atomic reactions that produce radio-activity, but we do already know some of the conditions capable of producing this phenomenon to a certain degree. In chemistry it is not necessary to know all the conditions of a reaction, but often only a small number of them, in order to cause that reaction to appear. A child knowing nothing of the mechanism of a steam engine may set it going by simply shifting the lever by which the steam is turned on. In the greater number of ordinary chemical reactions we work a little as the child does, without comprehending anything of the action of the mechanism and seeing only the final results.

SECTION 9.—*Modifications produced in matter by the partial dissociation of its atoms.*

We know that the products of the dissociation of atoms can not be recombined so as to form the bodies from which they originate. We also know that this dissociation can not be effected, at least by the means at present at our disposal, except for an infinitesimal quantity of matter. We must not, therefore, expect to find a very profound modification in matter only a small part of which has been dissociated. A modification does, however, necessarily exist. A body whose atoms have been partly dissociated is necessarily different from the same body before dissociation has commenced. What, then, are the modifications presented by bodies after the emission of effluvia from them?

Here we are obliged to leave for the moment the regions of pure experimentation and proceed by the way of conjectures and analogies. We are at the threshold of a new chemistry in which the ordinary reagents and balances can not help us at all, since we are dealing with reactions whose physical effects may be considerable, although the quantities of matter employed may be almost infinitely small.

We can, however, already say that the existence of this future science—intra-atomic chemistry—does not depend upon hypotheses alone. Numerous facts, scattered here and there, and hitherto unexplained, already give some scientific support to these hypotheses and seem to be about to soon transform them into solid realities.

These facts show us, indeed, that certain simple bodies may undergo transformations sufficient to change their most fundamental properties. I have shown this by my experiments with aluminum and magnesium, but it is shown still better with metals in the so-called colloidal state. When in that state, even though they are diluted to an incredible degree since according to Bernek colloidal platinum is

very active in a dose of a three hundredth of a milligram of the metal to a liter of water—they take on properties so intense and peculiar, so different from those which they possess in an ordinary state, that we can only compare them to certain organic compounds called diastases. It is found also that they act by their presence alone—that is to say, without appearing in the final product of the reactions. Chemists use the term "catalytic action" to explain analogous facts. The body supposed to act only by its presence is perhaps the seat of special atomic disaggregations which are not shown by reagents. We will indicate further on experiments on phosphorescence that support this consideration.

These metals in a colloidal state are obtained by various processes, the severest of which is the passing through distilled water of an electric arc between two poles made of the metal to be transformed, platinum or gold, for example.[a] After a certain time the water contains, in a form totally unknown, something derived from the particles of the metal, and that in the infinitesimal dose I have mentioned above. The liquid is colored, but it is impossible to separate anything from it by filtration or to perceive by the microscope any particles in suspension, which leads us to suppose that these particles, if they exist, are less than a wave length of light—that is to say, the thousandth of a millimeter. It does not seem possible to admit that the metal thus transformed is in a state of solution,[b] for the water that contains it presents none of the characters of a solution, such as a changing of its freezing or boiling points, the tension of its vapor, etc. In my opinion, the metal is found in the state of matter that has suffered a commencement of dissociation, and it is exactly for that reason that the colloidal metal prepared by the electric arc possesses none of the qualities of the body from which it was derived. Colloidal platinum or gold are certainly not ordinary gold or platinum, though they are made from those metals.

The properties of these colloidal metals are, indeed, without any analogy with those of a salt or even of a metal in solution. By certain of their reactions they resemble organic compounds rather than brute matter. That is the reason why they have been compared to the toxines, a kind of diastases of unknown chemical composition generally formed by bacteria, from which they can be separated by filtration, and which in imponderable doses produce tremendously active effects.

[a] The metals called "colloidal," like silver, for example, that are now found in commerce, are really simple chemical combinations and have very different properties.

[b] This would not be theoretically impossible, notwithstanding the supposed insolubility of metals, since a 20-franc piece placed in distilled water for a short time leaves in the latter traces of the copper which it contains as alloy in a quantity that can not be shown by reagents, but which is still sufficient to poison certain algæ.

According to M. Armand Gautier, two drops of tetanic toxine, containing 99 per cent of water and only 1 per cent of the active body, is sufficient to kill a horse. "A gram of this body," he says "would kill 75,000 men."

Metals in a colloidal state are exactly like toxines or organized ferments. Colloidal platinum decomposes oxygenated water, as do certain ferments from the blood; by oxidation it transforms alcohol into acetic acid, as does the *Mycoderma aceti*. Colloidal iridium decomposes the formate of lime into carbonate of lime, carbonic acid, and hydrogen, as is done by certain bacteria. A still more curious thing is that bodies like prussic acid, iodine, etc., that poison organic ferments[a] also paralyze or destroy the action of colloidal metals. It is necessary to invoke all the weight of our classical ideas concerning the invariability of chemical species in order not to see, in a body whose properties are so profoundly different from those from which it is derived, a totally new substance.

It is evident, however, that the opinion of chemists as to the invariability of atoms appears to rest upon a very solid basis, since, after all the transformations a body may undergo, we may always regenerate the body. Sulphate of copper bears no resemblance to metallic copper, but copper can be formed from it without difficulty. This argument will retain its value so long as we do not succeed in dissociating sufficient quantities of matter, or at least as long as we do not possess the physical means for revealing the transformations, often very slight, that occur in a body in which a small amount of dissociation has taken place. When a metal is modified by a partial dissociation it is changed too little for us to be able to prove it by the ordinary chemical reactions.

Only physical reactions can give evidence of such modifications. Radium and phosphorescent bodies furnish an excellent proof of this. As concerns radium, for example, we know that in its chemical reactions it is entirely identical with barium. It differs from it enormously, however, by its radio-active properties—that is to say, by the permanent dissociation of its atoms, which physical means alone can reveal.

As to the marvellous phenomenon of phosphorescence, it likewise affords an example of substances chemically identical which yet present an entirely novel physical property under the influence of traces of foreign substances that probably act by producing a commencement of dissociation. The sulphides of calcium or of barium are never

[a] The action of the poison varies with different toxines. They resist some energetic reagents and are influenced by traces of reagents that would seem to possess but little activity. M. Armand Gautier has shown that bodies as violent as prussic acid, corrosive sublimate, and nitrate of silver are without effect upon cobra venom, while mere traces of alkaline matter prevent its action.

phosphorescent when pure. Augmented by traces of certain foreign substances and submitted to the action of an elevated temperature which produces dissociation of matter in all bodies, as I have shown in a preceding paper, these same sulphides soon become capable of producing phosphorescence. These examples might be multiplied.

We must not, then, ask chemistry to inform us as to the transformations that matter undergoes when it begins to become dissociated. It is also evident that the only means possessed by that science are sometimes altogether too gross for the differentiation of bodies, and sometimes do not succeed in differentiating them at all. Nearly a quarter of the elementary bodies already known—that is to say, about fifteen—so resemble each other in their chemical characters that without certain physical properties (spectroscopic lines, electric conductibility, specific heat, etc.) they would never have been separated. These bodies are the metals whose oxides form what are called the rare earths. "They are distinguished from each other," say Messrs. Wyrouboff and Verneuil, "with some two or three exceptions, only by their physical properties, and are found to be chemically identical. They are so much so that by no reaction hitherto devised can they be separated, and we are reduced to obtaining them in a more or less pure state by the empirical and gross process of fractional distillation." In no other manner, indeed, can we obtain radium.

If we marshal the facts cited we arrive at this conclusion—incontestable in the case of barium and radium, incontestable in the case of certain phosphorescent bodies, almost incontestable in the case of metals in a colloidal state—that reactions having for their probable origin beginnings of atomic dissociation suffice to give to bodies absolutely novel properties which none of our chemical reagents can detect, and which were revealed only when new means of physical investigation were discovered. Ordinary chemistry touches only, I repeat, the structures formed by atoms and modifies them at its will. If, however, it disposes at will of the stones of the structures, it does not yet know how to affect the constitution of those stones. The intra-atomic chemistry of the future will attempt the study of the phenomena which take place within the atoms. In this new science, of which we barely discern the dawn, the old paraphernalia of the chemists—their balances and their reagents—will probably remain unemployed.

SECTION 10.—*Phases of existence of matter Genesis and evolution of atoms.*

Birth and evolution of atoms.—It is hardly thirty years since it would have been impossible to write on this subject a single word deduced from any scientific observation whatever, and one might have supposed that the history of atoms would always be enveloped in

darkness. How, indeed, was it possible to suppose that they could evolve? Was it not universally admitted that they were indestructible? Everything was changing in the world, and everything was ephemeral. Beings succeeded each other, always taking on new forms; stars ended by becoming extinguished; the atom alone was not subjected to the action of time, and seemed eternal. The doctrine of its immutability reigned for two thousand years, and nothing seemed to indicate that it could ever be shaken.

We have detailed the experiments which resulted in the crumbling away of this antique belief. We know now that matter disappears slowly and that the atoms which compose it are not destined to last forever.

If, however, atoms are condemned to a relatively ephemeral existence, it is natural to suppose that they were not formerly what they are to-day and that they must have evolved during the course of ages. What were they formerly? Through what successive phases have they passed? What gradations of form have they assumed? What were formerly the various material substances which now surround us—stone, lead, iron; in a word, all bodies?

Astronomy alone can answer, in some degree, such questions; and, indeed, it has done so. Knowing how to penetrate by spectral analysis into the structure of stars of various ages that illuminate our nights, it has been able to show us the transformations that matter undergoes at its earliest stages.

The eminent astronomer, Sir Norman Lockyer, director of one of the large English observatories, first showed this evolution of matter in the stars, and was also the first who dared to maintain that the atoms of elementary bodies were dissociable.[a]

The proofs that he furnished of this last assertion were convincing, but minds were not then prepared for them, and it was necessary to wait till the discovery of the cathodic radiations and the radio-activity of matter before the antique doctrine of the indestructibility of atoms could be shaken.

The point of departure of the researches of Sir Norman Lockyer was this fundamental fact that, contrary to the ideas that first prevailed, the spectrum of each chemical element varies according to the temperature to which the element is submitted. For example, the spectrum of iron in an ordinary flame is quite different from the spectrum of the metal in the electric arc. In the flame it presents only a small number of lines. In the arc it presents nearly 2,000 of them. The spectrum of the same metal likewise varies according as we observe it in the hottest or the less hot portions of the sun. In tubes containing

[a] The researches pursued by Sir Norman Lockyer during twenty-five years have been published by him in a recent book, Inorganic Evolution, London, 1900.

rarefied gases traversed by an electric discharge, the same gas, nitrogen, for example, may give different spectra, according to the degree of the vacuum.

Carrying, then, his investigations to the stars, the same astronomer showed that the whitest ones—which are also the hottest, as is proved by the prolongation of their spectrum into the ultra violet—are composed of only a very small number of chemical elements. Sirius and α-Lyra, for example, are composed almost exclusively of hydrogen. In the red and yellow stars, which are less hot, having begun to cool, and therefore are older, we see the other chemical elements successively appear. First, magnesium, calcium, sodium, iron, etc., then the metalloids, the latter being seen only in the earliest stars. It is, therefore, only as their temperature lowers that the elements of the atoms can group themselves so as to form the elementary bodies. Sir Norman Lockyer finally arrives at the following conclusion: "The chemical elements are, like plants and animals, the product of evolution."

The preceding observations seem to definitely prove, conformably, indeed, to one of the oldest theories of chemistry, that the various elementary bodies were derived from a single substance. Hypothesis begins only when we suppose that this primitive substance was produced by a condensation of the ether.

It appears doubtful whether heat was the only cause of the transformation of atoms. Other unknown forces must, probably, have acted. What these forces were is, however, of no consequence; the essential fact is that observation of the stars shows us the evolution of atoms and the formation of various bodies under the influence of that evolution.

Mobility and sensitiveness of matter.—We have now reached that phase of the history of atoms in which, under the influence of unknown causes whose effects only we can ascertain, they have finally formed the various elementary bodies that make up our globe and all the beings that live upon its surface. Matter is born and will persist during a long succession of ages.

It persists with various characteristics, of which the most marked appears to be the stability of the atoms that compose it. They serve to form chemical structures whose form readily varies but whose mass remains practically invariable throughout all changes.

The materials of the chemical structures are then very stable, but these structures are sometimes of very great fragility and always of extreme mobility. The least variations of the environment—temperature, pressure, etc.—instantly modify the movements of rotation and oscillation of the atoms of which matter is made up.

These modifications are rendered easy by the granular state of matter. We are obliged to admit, in fact, that the atoms that compose it

never touch each other, and are only kept together by a special force called cohesion. It is this which permits bodies to retain their form. If it were possible to annul it by a magic wand, or more simply by an antagonistic force, we would instantaneously reduce into an atomic dust a block of metal, a rock, or a living being. We could not even perceive this dust, for atoms do not seem to possess any properties that could render them visible to our eyes.

If atoms are simply a condensation of energy we might say that the matter most rigid in appearance—a block of steel, for example—simply represents a state of mobile equilibrium between the condensed energy that constitutes it and the various energies, heat, pressure, etc., that surround it. Matter yields to their influence as an elastic thread obeys tractions to which it may be subjected, yet resumes its form as soon as the traction ceases.

The mobility of matter is one of its most easily demonstrated characteristics, since it is only necessary to place the hand near a thermometer bulb to cause the column of liquid to become at once displaced. Its molecules are then separated from each other under the influence of slight heat. When we place the hand upon a block of metal the movements of rotation and oscillation of its atoms are likewise modified, but so slightly that we fail to perceive it, which is precisely the reason why matter appears to us to possess very slight mobility.

The general belief in its stability seems likewise confirmed by the observation that in order to cause considerable modifications in a body—for example, to melt it or to reduce it to vapor—it is necessary to employ very powerful means.

Sufficiently precise methods of investigation show, on the contrary, that not only is matter extremely mobile, but also that it possesses a sensitiveness that no living being has ever approached.

Physiologists measure, as is well known, the sensitiveness of a being by the degree of excitation necessary in order to obtain from it a reaction. The being is considered as very sensitive when it reacts under slight stimuli. Applying similar tests to brute matter we can show that the most rigid substance and the least sensitive in appearance, a bar of metal, for example, is really incredibly sensitive. The matter of the bolometer, formed essentially of a thin thread of platinum, is so sensitive that it reacts—by a variation of electric conductibility—when it is struck by a ray of light having an intensity so feeble that it can produce an elevation of temperature amounting to only one hundred millionth of a degree.

With improvement in our means of investigation this extreme sensitiveness of matter and the mobility that necessarily accompanies it become more and more manifest. M. H. Steele lately showed that it

is sufficient to lightly touch an iron wire with the finger to cause it to become at once the seat of an electric current. It is known that at a distance of hundreds of kilometers the Hertzian waves, whose energy at such distances is infinitely feeble, profoundly modify the structure of the metals that they reach, since they change in a marked degree their electric conductibility. On this phenomenon wireless telegraphy is based. Various physicists admit that under the influence of these waves metals instantly undergo allotropic transformations analogous to those that light produces in certain bodies, notably phosphorus and sulphur.

This extraordinary sensitiveness of matter, so contrary to what common observation seemed to indicate, becomes more and more familiar to physicists, and this is why an expression like "the life of matter," devoid of sense only twenty-five years ago, is now in current use. The study of brute matter reveals more and more properties that formerly seemed the exclusive endowment of living beings. M. Bose, investigating the fact that "the most general and delicate sign of life is the response to an electric current," proved that this electric response, "considered generally as the effect of an unknown vital force," exists in matter. He shows also by ingenious experiments[a] "the fatigue" of metals and its disappearance after repose, the action of chemical excitants and depressants, the action of poisons on these same metals, etc.

The dissociation of atoms and the disappearance of matter.—Until very recently the indestructibility of the elements that compose matter was considered as the most fundamental dogma of chemistry.

Nor was it vulgar observation alone that taught this; all the experiments of chemistry had only served to confirm it since, throughout all the transformations that matter might undergo, its mass, measured by its weight, remained invariable. This invariability of mass had even come at last to be the only truly irreducible characteristic of matter – that is to say, the only one that appeared to be independent of the influences of the environment. The other properties, being always conditioned by the environment, appeared to be simple relations.

I have recalled in this paper and examined in detail in a preceding one the facts demonstrating that matter can be dissociated, and consequently that its mass can not be considered as an invariable quantity. It is needless to return to this now. Let us consider the fact as established and try to explain it.

The explanation will necessarily be hypothetical, as the conception upon which it rests is an hypothesis. According to our present ideas regarding the constitution of atoms, each of them may be considered as a veritable solar system comprising a central part, around which turn with great velocity at least a thousand particles and sometimes

[a] Journal de Physique, August, 1902.

many more. The latter must then possess great kinetic energy. If any cause whatever disturbs their trajectory, or if the rapidity of their rotation becomes sufficient for the centrifugal force resulting from it to overcome the attractive force that maintains them in their orbit, the peripheral particles will then escape into space, following a tangent of the orbital curve. By this emission they will give rise to phenomena of radio-activity. To attempt to briefly explain why these particles whirl about each other since the origin of things would be useless.

Whatever may be the value of this explanation, the fact of dissociation exists. It is very singular, surely, to see a system as stable as that of the atom begin to dissociate under influences so slight as a ray of light or very simple chemical reactions, but these are facts of experience before which we must bow.

When it was thought that radio-activity was peculiar to certain bodies, such as uranium and radium, it was believed, and is still believed by physicists, that the instability of these bodies was a consequence of their high atomic weight. This explanation disappears before the fact demonstrated by our former researches that it is just the metals of the lowest atomic weight, such as magnesium and aluminum, that become the most easily radio-active under the influence of light, while, on the contrary, those of high atomic weight, such as gold, platinum, and lead, have the lowest radio-activity. Radio-activity is then independent of atomic weight and is probably due, as I have suggested, to certain chemical reactions of unknown nature. Two bodies, not radio-active, may become so by combination. Mercury and tin, for example, are among the bodies having lowest radio-activity under the influence of light. I have shown, however, that mercury becomes extraordinarily radio-active under the influence of light as soon as there are added to it some traces of tin.

This example and all similar ones will show that, as said above, the causes that produce dissociation of atoms are often very slight. How do they act? Of this we are completely ignorant. Some metals that become very radio-active under the influence of luminous rays, having a certain wave length, lose this activity almost entirely under the influence of rays whose wave length is but slightly different. These facts seem to have an analogy with the phenomena of resonance. It is well known that an organ pipe or a heavy bell may be made to vibrate by sounding near it a note of a certain vibratory period, while the most violent noises may not affect it.

Whatever may be the causes capable of dissociating in some slight degree the aggregate of condensed energy constituting the atom, those causes exist, and when we know them better we shall certainly succeed in obtaining a more complete dissociation than we now do. It was sufficient, in the present state of science, to prove its existence.

What becomes of the elements dissociated from atoms? They have lost, as we have shown, their material character, and we suppose that they are made up of electric particles. Where do these particles go to?

We are here at the extreme limits of our knowledge and are reduced to replacing explanations by conjectures and interrogation points. We have seen the material atom become dissociated. Matter considered as energy condensed under a form in which it acquires weight, form, and fixity has become transformed into imponderable elements that are no longer matter, but are not yet ether. Of their destiny we are still entirely ignorant.

We know by experiment that they can not again form the matter from which they were derived. Does the electric atom, which all modern ideas lead us to consider as a localized modification of the ether, having a permanence in the ether, preserve its individuality indefinitely? Is it eternal while matter is not so?

Whether it remains isolated or associates itself with matter having a contrary sign matters little. Even though by such an association it should form an atom of neutral electricity—an unknown thing, shown as yet by no experiment—it possesses an individuality. But how long a time does it keep it? If it does not keep it, what does it then become?

That the atom of electricity that necessarily had a beginning is destined to have no end seems hardly probable. If all electric atoms persist, while their formation is continuous under the influence of so many diverse causes, they would finally accumulate to such an extent that they might form a new universe or at least a sort of nebula. It is therefore probable that they end by losing their individual existence. But how can they then disappear? Can we suppose that their destiny is like that of the blocks of ice that float about in the polar regions and preserve their individual existence so long as they do not encounter the only cause that can destroy them—an elevation of temperature? As soon as this cause of destruction acts upon them they vanish and disappear in the ocean. Such, perhaps, is the final destiny of the electric atom. When it has radiated all its energy it disappears in the ether and is no more.[a]

[a] This conception evidently does not agree with the first principle of thermodynamics; but if the dogma of the indestructibility of matter is taken away, that of the conservation of energy seems likewise somewhat menaced. However, the question is too important to be discussed here, and we will take it up in another paper. It seems very probable, and I am not alone in so thinking, that the law of the conservation of energy, whose uncertain limits have been so brilliantly demonstrated by M. Poincaré in his recent work, La Science et l'Hypothèse, is, like most physical laws, like that of Mariotte, for example, true only within certain limits. It would, then, be useful to preserve it for convenience in calculations.

If the views set forth in this paper are correct, there exist four successive forms of matter. Two are known to us by experience; the first and the last are as yet hypothetical.

The first form is that exhibited by the ether.

The second that of ordinary matter, formed of atoms which are, according to our view, only condensed energy in a special state, from which result form, weight, and fixity.

The third form, with which dissolution commences, is represented by the so-called electric atom, a substance intermediate between ordinary matter and the ether—that is to say, between the ponderable and the imponderable. The matter has lost its weight, its inertia is no longer constant, and its fixity seems to be transitory.

The last phase of the existence of matter would be that in which the electric atom, having lost its individuality—that is to say, its fixity—disappears in the ether. This would be the final term of the dissociation of matter, the final nirvana, into which it seems that everything must return after an ephemeral existence.

Yet these are merely interpretations. We must not depart from the facts set forth and which have proved that atoms become dissociated.

Since, too, we have proved that this dissociation is a general phenomenon, we are authorized to conclude that the doctrine of invariability of atomic weights, on which all modern chemistry is founded, is only a deceptive appearance, resulting entirely from the want of sensitiveness in balances. If they were sensitive to the millionth of a milligram, they would show that all our chemical laws are merely approximations. If balances were capable of such precision, we should soon show that under many circumstances, and particularly during chemical reactions, the atom loses a part of its weight. We are then authorized to conclude, contrary to the principle stated by Lavoisier as the basis of chemistry, that we never find in a chemical combination the total weight of the bodies employed to produce that combination.[a]

The correctness of this capital fact begins to be recognized by eminent physicists. For example, recently before the Physical Society of

[a] We are already beginning to prove this experimentally by using extremely sensitive balances and operating during a sufficiently long time. "By the aid of a balance of great precision," writes M. Lucien Poincaré, "MM. Landwolt and Heydweiler have weighed numerous bodies before and after the action of chemical changes which those bodies set up, and these two very expert and very cautious physicists have not been afraid to announce the sensational result that under certain circumstances the weight is not the same before and after the reaction. To particularize, the weight of a solution of sulphate of copper in water is not the exact sum of the weight of the salt and the water." (Revue des Sciences, January, 1903, p. 96.)

London Sir Oliver Lodge, referring to experiments in radio-activity, expressed himself as follows:

The evolution or transformation of matter is experimentally demonstrated by experiments upon radio-activity. The heavy atoms of radio-active bodies appear to collapse and throw off atoms of low atomic weight. It might be thought that this hypothesis about the degradation and instability of the atoms is mere speculation, but it is the most reasonable explanation of the observed phenomena. According to the electric theory of matter, i. e., on the view that the atom contains electrons with rapid intra-atomic movements obeying laws like astronomical laws, this instability ought to exist. We must not suppose that atoms are permanent and eternal. We may possibly find a rise and decay in ordinary matter. The history of an atom presents analogies with that of a solar system. On the electric theory of matter, the falling together of electrons might produce the electric aggregate known as an atom, and its subsequent gradual decay or separation into other forms would be accompanied by epochs of radio-activity. [a]

In an address, also quite recent, Sir William Crookes arrived at an analogous conclusion:

This fatal quality of atomic dissociation appears to be universal and operates whenever we brush a piece of glass with silk; it works in the sunshine and raindrops, and in the lightnings and flame; it prevails in the waterfall and the stormy sea. And although the whole range of human experience is all too short to afford a parallax whereby the date of the extinction of matter can be calculated, protyle, the "formless mist," once again may reign supreme, and the hour hand of eternity will have completed one revolution. [b]

Let us now recapitulate.

By this long analysis we have followed the atom from its birth to its decline. We have seen it forming, developing, then beginning to disappear. Trying to ascertain its nature we have shown that it constitutes a tremendous reservoir of energy, and is probably nothing but condensed energy susceptible of being slowly dissociated.

We are certainly ignorant of the nature and mode of action of forces capable of condensing a part of the ether that fills the universe into atoms of any gas whatever—such as hydrogen or helium, for example—then of transforming such gas into substances like sodium, lead, or gold, but the changes observed in the stars show that forces capable of producing such transformation actually exist, that they have operated in the past and still continue to operate.

According to Laplace's theory of cosmogeny the sun and planets were at first a great rotating nebula at whose center a nucleus formed and from which rings were successively detached, which later formed the earth and other planets. At first gaseous, these masses became gradually cooled, and the space primitively filled by the nebula was occupied only by a few globes that continue to rotate around their

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[a] Physical Society, session of June 3, 1903. Reported in Chemical News June 19, 1903.

[b] Chemical News, June 12, 1903, p. 281. [See also present Smithsonian Report, p. 241.]

own axes and about the sun. According to the new ideas concerning the composition of atoms, we are authorized to suppose that each of them was formed in a similar manner, and, in spite of its minute size, represents a veritable solar system.

Yet our nebula, like those which still continue to illuminate the night, necessarily came from something. In the present state of science we can only suggest the ether as a possible source from which this something arose, and that is why all investigations lead us back to considering it as the fundamental element in the universe. The worlds were born in it and they will die in it.

We are ignorant how an atom came to be formed and why it ends by slowly disappearing; but we at least know that a similar evolution is taking place in the worlds that surround us, since we can observe them going through all the phases of evolution from the nebula to the cooled star, passing through the stage of incandescent suns similar to our own. The transformations of the inorganic world now appear to be as certain as those of organized beings. The atom and consequently matter do not escape from this sovereign and mysterious law which rules over the birth, growth, and death of the innumerable stars which people our firmament.

It is in these atomic systems, which were ignored for so long a time because of their extreme minuteness, that we must doubtless look for the explanation of some of the mysteries that surround us. The infinitely little may perhaps contain the secrets of the infinitely great.

It is not only from a purely theoretical point of view that it is necessary to thoroughly study the atomic systems and the tremendous energies that work within them. Science may be on the eve of capturing these energies whose existence was unsuspected and thus render unnecessary the mining of coal. The provision of combustibles that the terrestrial strata contain is rapidly becoming exhausted, and if this reservoir of energy fails, manufactures, the essential element of civilization, are destined to perish. Without coal, indeed, railroads and steamboats would be stopped, factories closed, and electric lights extinguished. The man of science who finds the means of economically liberating the forces that matter contains will almost instantaneously change the face of the world. An illimitable source of energy being gratuitously at the disposal of man, he would not have to procure it by severe labor. The poor would be the equals of the rich, and the social question would be no longer agitated.

THE ELECTRIC FURNACE.[a]

By J. Wright.

There are few inventions in the electrical field which have benefited the chemist and metallurgist more than that comprised under the general title of "electric furnace." Up to, comparatively speaking, a few years ago the highest attainable temperature by any known artificial means was 1,800° C., or, possibly, with exceptional facilities and the exercise of great care, as high a temperature as 2,000° C. may, in some cases, have been attained, though the exact limit is questionable; certainly it does not rise much above the latter figure. Thanks, however, to the indefatigable researches of Moissan, Siemens, Borchers, Cowles, and some other investigators, we now possess a means for the artificial production of temperatures far above this limit, which enable us to fuse and otherwise treat commercially such hitherto refractory substances as chromium, platinum, carbon, and even the once indestructible crystalline form of that element, the diamond.

Generally speaking, electric furnaces may be divided under two main headings, namely, those in which the heating effect is produced by the electric arc established between two carbon or other electrodes connected with the source of current, commonly known as arc furnaces; and those in which the heating effect is produced by the passage of the current through a resistance, which either forms part and parcel of the furnace proper, or is constituted, by a suitably conducting train, of the material to be treated in the furnace. The principle of this latter type is analogous to that involved in the heating to incandescence of the ordinary electric-lamp filament, and such furnaces are, as a class, known as resistance furnaces.

The earlier electric furnaces naturally assumed an experimental form, and of these that devised by Moissan, the celebrated chemist and investigator, is probably the simplest. It is an arc furnace, and consists of two chalk blocks bored out at their centers to receive a carbon crucible, which incloses the center or hearth of the furnace proper. Into this cavity pass two massive carbon electrodes, through openings provided for them in the walls of the structure, which is held together by massive clamps. Suitable terminal connections to

[a] Reprinted, by permission, after revision by the author, from Cassier's Magazine, June, 1903.

the carbon rods are provided, exterior to the furnace, and the arc established between their inner extremities when the current is turned on plays over the center of the crucible, heating its contents.

A furnace of this type, though its capacity is limited to a single charge of the crucible at each operation, has nevertheless proved itself of extreme utility in laboratory practice, and is a very efficient source of heat in that the hearth or center of activity is entirely surrounded by refractory, nonconducting walls. Very little heat is, consequently, lost by diffusion or radiation.

A somewhat more elaborate modification of Moissan's original furnace has been devised by Messrs. Ducretet & Lejeune, of Paris, and is shown in fig. 1. It consists of a refractory chamber R, built of fire brick or some other suitable material, and provided with an opening A, through which the substances to be treated may be introduced. C C are carbon rods supported in massive tubular clamps T T, which are water-jacketed to keep down their temperature to a safe limit. B is a carbon or magnesia crucible, forming the hearth of the furnace and containing a charge of the material to be treated, while W is a remov-

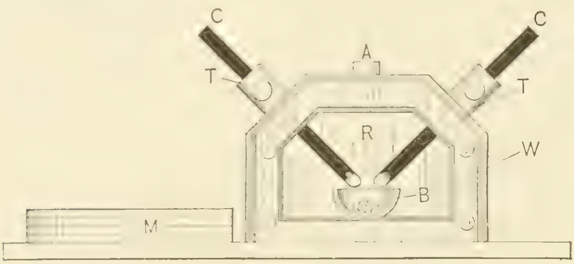


FIG. 1.

able window or inspection opening, fitted with ruby glass, through which operations requiring only a moderate heat can be watched while in progress. When utilized for higher temperatures, this glass slide is replaced by a slab of refractory material, such as fire brick. The carbons C C project through the walls of the furnace at right angles to each other, and the necessary separation of their inner extremities for the establishment of the arc takes place at a point just above the mouth of the crucible B, as shown. A system of tubes leads into the interior of the chamber R, and serves, when required, for the introduction of special gases with which it may be necessary to cause the contents of the crucible to enter into chemical combination. A horseshoe permanent magnet M, manipulated at the exterior, exerts a repellant force upon the arc, directing it down into the crucible as desired, after the manner of a blowpipe.

Sir William Siemens was the first to apply the electric arc furnace to commercial operations, and his apparatus and experiments were described in a paper read by him before the Society of Telegraph

Engineers. According to this astute investigator, who seems to have, in a measure, grasped the conditions and general principles necessary to the successful operation of an arc furnace—no mean conception, when one considers the general lack of knowledge on the subject which prevailed at the time (over twenty years ago)—the advantages in favor of the electric furnace as a source of heat are that, theoretically, the heat obtainable is unlimited; fusion is effected in a perfectly neutral atmosphere; the operation can be carried on in a laboratory, without much preparation, and under the eye of the operator; and that the limit of heat practically obtainable with the use of ordinary refractory materials is very high, because in the electric furnace the fusing material is at a higher temperature than the crucible, whereas in ordinary fusion the temperature of the crucible exceeds that of the material fused within it.

The general principle of the early Siemens arc furnace is represented in fig. 2, in which B is a refractory crucible of plumbago, magnesia, lime, or other suitable material, which may be varied according to the nature of the substance to be dealt with. It is supported at the center of a cylinder or jacket J, and is packed around with broken charcoal, or a similarly poor conductor of heat. Being thus isolated, as it were, from the surrounding atmosphere, it retains its heat, and very little is lost by diffusion. The negative electrode consists of a massive carbon rod C passing vertically through the center of the lid of the crucible and free to move vertically therein, though the clearance opening is, for obvious reasons, very small. The rod C is suspended from the lower end of a copper strap S, which conducts the current from it, being attached at its upper end to the curved extremity of a horizontal beam A. The other side of the beam is provided with an adjustable weight W, and carries, suspended from its extremity by a hinged joint, a hollow soft-iron cylinder e, forming the core of the solenoid E. P is a dash-pot arrangement in which the cylinder works, the tendency of E being to raise it out of P against the counteracting force of the weight W, thus lowering the negative electrode into the crucible. The solenoid winding is connected as a shunt across the two electrodes. The positive electrode F, which may be of iron, platinum, or carbon, consists of a rod of one or the other of these materials passing up through the center of the base of the crucible. The furnace was originally designed by Siemens for the

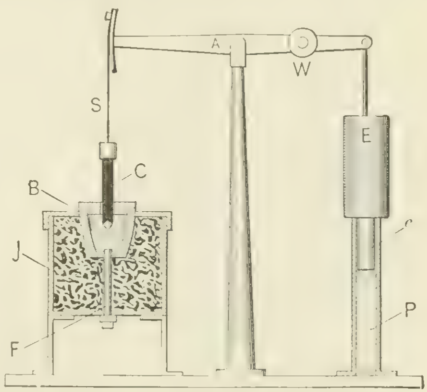


FIG. 2.

fusion of refractory metals and their ores; consequently, once the action is started, electrical contact is established between the lower electrode F and the semimetallic mass in the crucible, and the arc continues to play between the surface of the mass and the movable carbon rod C. As the current through the furnace increases, that through the shunt winding of the solenoid diminishes, and the weight W coming into play causes its end of the beam to descend, thereby raising the negative electrode C and restoring equilibrium.

The Willson furnace is essentially a modification of Siemens's original form, the solenoid regulation of the upper movable carbon being replaced by a worm and hand wheel, while the furnace is made continuous in operation by the provision of a tapping hole for drawing off the molten products. This type of furnace was employed in the manufacture of calcium carbide, which, when drawn off in a molten state, is much purer than the ingot or broken-lump form, in which the greater bulk of that commodity is placed on the market.

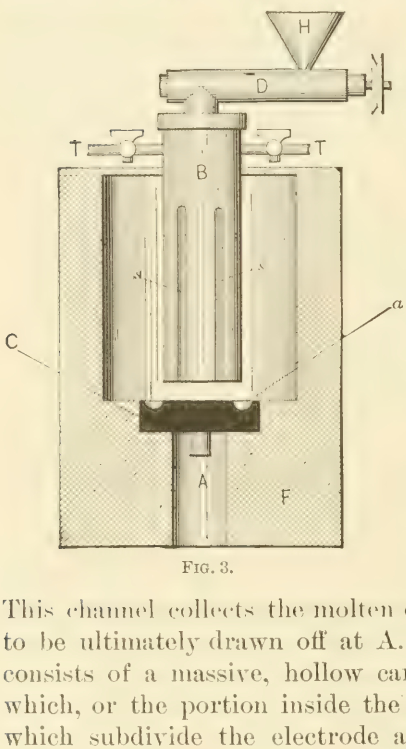


FIG. 3.

The Parks carbide furnace, devised by W. P. Parks, of Chicago, is of the arc variety and provides for the production of calcium carbide in the molten state. It is represented in fig. 3 and consists of a vertical cylindrical structure F of refractory material, provided with a carbon hearth C, which at the same time acts as the negative electrode. It has an annular channel *a* cut in its upper surface, which latter is flush with the inner floor of F. This channel collects the molten carbide formed, and it drains down, to be ultimately drawn off at A. The upper, positive, electrode B consists of a massive, hollow carbon cylinder, in the lower half of which, or the portion inside the furnace F, are cut radial slots *s s*, which subdivide the electrode and tend to set up a circle of arcs around the space bounded by the hearth. T T are gas-supply pipes, ending in hydrocarbon burners inside of B, which primarily heat the raw material as it passes down the hollow center of the electrode. The feeding is effected from a hopper H by an Archimedean screw working in the casing D.

An electrolytic furnace, utilized in the separation of aluminum from a mixture of purified alumina and cryolite, is that adopted in what is known as the Herault process, which is being worked by the British

Aluminium Company, of Foyers, New Brunswick, and one or two metallurgical firms on the Continent.

It consists of an outer iron casing or container F (fig. 4) resting on an insulating base. This container is lined with massive carbon plates, cemented together with tar or suitable conducting material, and so arranged as to form at the center a recess or hearth H, an outlet *o*, from the bottom leading out to the exterior of the furnace, and providing for drawing off the molten metal.

A series of copper pins *c c*, driven into the iron walls of the container, serve as a means of terminal connection to the carbon blocks, which constitute one electrode of the furnace, while the other, C, consists of a number of carbon plates, placed face to face, like the leaves of a book, the spaces between being filled in with some good electrical conductor, such as sheet copper. The composite electrode thus built up is mounted in a frame E, by means of which it can be raised or lowered as required, and terminal connection is secured by means of an encircling clamp T. The electrode C passes through a clearance opening in the lid L of the furnace, which consists of graphite plates; openings *p p* are also provided for the introduction of the raw material (alumina and cryolite), thereby making the furnace continuous in operation.

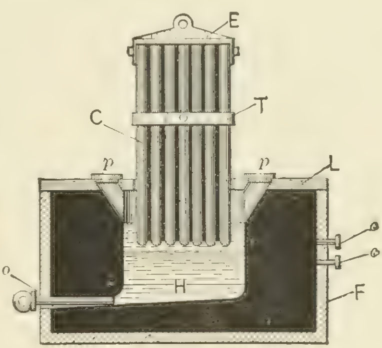


FIG. 4.

The furnace is charged with purified alumina and cryolite, as already indicated, and, the electrode C having been lowered, the action is started. The heat thus set up, combined with the electrolytic action of the current, results in the setting free of metallic aluminum, while oxygen gas is evolved at the positive or carbon electrode and enters into combination with it, forming the gases monoxide and dioxide of carbon.

The molten aluminum collects at the bottom of the hearth and is tapped off through the outlet *o*, fresh material being fed in and the height of the electrode C regulated as the operation proceeds.

The King furnace is also of the arc variety and is utilized in the manufacture of carbide in ingot form. It consists of a fire-brick chamber, through the roof of which passes vertically the upper adjustable electrode. The lower, fixed, electrode is carried by a small truck or trolley, which runs along rails at the base of the structure and acts the part of crucible or hearth. The lime and carbon are fed into it down lateral channels in the walls of the furnace and are caused to combine by the heat of the arc set up. The upper electrode is gradually raised as the raw material is fed in, until, at a certain point, the

truck becomes filled with a block or mass of calcium carbide and is then wheeled out of the furnace to discharge its load. While fusion is in progress a slight reciprocating motion is given to the truck, which serves to shake the charge well down and introduce fresh portions of it into the path of the arc proper.

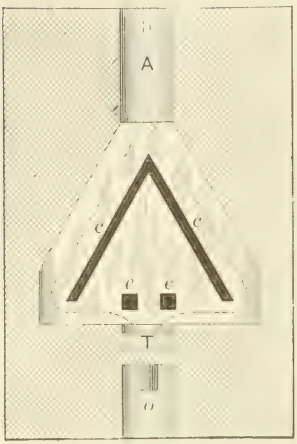


Fig. 5.

The Chavarria-Contardo arc furnace for the manufacture of calcium carbide possesses several novel points. Its general principle is represented diagrammatically in fig. 5, where *e e* are the electrodes, running parallel to one another and slightly above the axis of the channel or trough T, which forms the hearth; *c c* are thin graphite plates, built up to form a roof-shaped structure, which becomes itself intensely hot when the furnace is active. The raw material is fed in at A, and, passing over the upper surfaces of *c c*, receives a preliminary heating of no mean degree; it then passes down, taking the course indicated by the dotted lines, under the electrodes *e e* and into the trough T, where it is subjected to the most intense reflected heat of the arc. The molten carbide formed is drawn off by way of the outlet *o*.

The disposal of the gases, especially carbon monoxide, resulting from the reactions in a carbide furnace has long been a stumbling block to the manufacturer in that any attempt at modifying the furnace to this end resulted in undesirable complications and increased prime cost. This has been, in a measure, overcome in the Frölich arc furnace for carbide manufacture, invented by Dr. Oscar Frölich, of Streglitz, Germany. The general arrangement is shown in fig. 6 and consists of a cylindrical iron crucible F, mounted on standards S, and tapering at its base to a central discharge orifice.

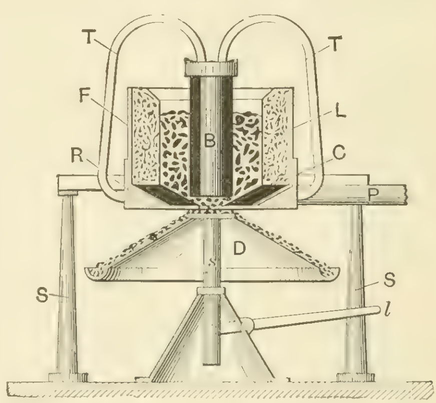


Fig. 6.

A lining of fire clay L protects the cylindrical wall, while the inner surface of the conical base is covered by the carbon electrode C. The remaining electrode consists of the massive carbon cylinder B, which is hollow, and depends, with its lower edge just over the discharge orifice, the arc taking place between the two edges of the

carbons. Tubes T T lead from the upper portion of the carbon cylinder B to the annular chamber R, just outside and inclosing the space bounded by the lower electrode C. The gases of combustion pass up the center of B, which acts as a flue, and down by way of the tubes T T to R, where they mingle with air, admitted through perforations in the casing, and are consumed, the final products passing out through the discharge pipe P.

The raw material is fed into the mouth of the furnace around the central electrode, and, passing through the annular arcing region at the bottom, where it becomes converted into carbide, falls onto the adjustable conical table D. This is provided with a lip around its lower edge and is mounted on a stem *s*, which, gearing with the lever *l*, permits of its being raised or lowered according as the operation of the furnace is intermittent or continuous.

The Denbergh furnace for the manufacture of sulphuric and phosphoric acids, and also "water-glass," or sodium ortho-silicate, is shown in fig. 7. It consists of an ordinary fire-brick structure F, lined at *r* with a refractory material impervious to the gases produced in the reactions, an outlet for which gases is provided at *o*. The body of the furnace is contracted below, as shown, and the outlet R for the fused products is led up within the walls themselves, from the point of lowest level to another point of higher level, which defines the depth of converted material contained within the furnace.

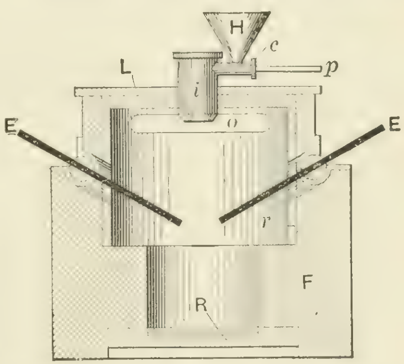


Fig. 7.

The lid L carries a charge inlet *i* and a hopper H, the feeding being secured mechanically by a reciprocating movement communicated to the piston *p*, which works in a cylinder *c*, carrying a definite quantity before it at each stroke. The electrodes E E are of carbon, passing through terminal sockets in which they are capable of motion in a direction corresponding with their axes, which permits of feeding as they wear away, whilst the sockets, in turn, are mounted in a species of swivel joint, which allows the angle of inclination, and consequently the height of the arc, to be varied at will.

Koller's arc furnace is of a simple description. It consists of a longitudinal chamber, with massive carbon blocks projecting through the end walls. A series of carbon blocks, supported in line with the terminal electrodes, are arranged along the chamber at regular intervals, their number varying according to the voltage. The arc is thus split up into series, and a number of heated regions are secured in the center of the mass of raw material which is packed around the blocks.

The Henriveux furnace, for the manufacture of glass, consists of three steps or slabs of refractory material, forming a species of cascade, the mixture to be fused being fed from a hopper onto the top step, whence it descends by gravity over the remainder. The heat from a powerful arc is directed upon each of the three steps, and the mass, in passing through the series of three, emerges finally in a molten state, and is collected in a suitable receptacle at the bottom, where it is maintained in a state of fusion by a gas or coke fire. It is said to be a very wasteful process in that a considerable quantity of the heat developed in the arcs is lost or dissipated without performing useful work.

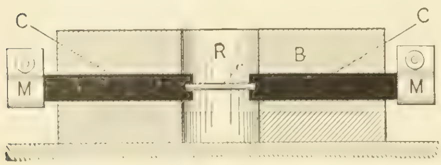


FIG. 8.

Passing now to resistance furnaces, Borchers's is typical of that class in which a core, forming part of the furnace itself, is heated by the passage of the current through it, and imparts its heat to the surrounding mass of material contained in the furnace. It is represented in fig. 8, and consists of a block B of refractory material, through the center of which passes an opening R, forming the crucible or center of activity into which is fed the material to be treated. This space R is bridged by a thin carbon rod *c*, which is attached at its extremities to two massive carbon electrodes C C, passing through the walls of the furnace and fed with current through the large metal clamps M. These massive electrodes serve to conduct the current without undue heating to the smaller rod *c*, through which it passes in turn, raising it to a very high temperature, owing to the resistance offered to its passage by a conductor of considerably smaller cross section, and forming, as it were, a central, heated axis to the material contained in the crucible. It thus diffuses its heat throughout the mass from its center outwards.

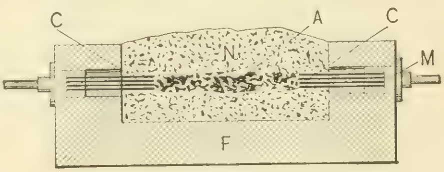


FIG. 9.

The Gibbs resistance furnace is based on the Borchers principle, a carbon rod, or rods, of small section being supported between massive carbon blocks set in cast-iron sockets let into the brickwork. The novelty of this invention, however, lies in the position of the small resistance rods. These are located above the furnace charge and do not come into actual contact with it at all, the heat being communicated by reflection from the domed roof.

The Acheson furnace for the manufacture of carborundum is a somewhat rudimentary device, in that it is built up and pulled down again for each charge of raw material dealt with. It is represented in diagram by fig. 9, in which F is a rough fire-brick structure, through

the end walls of which project the electrodes C C, consisting of composite bundles of carbon rods set in massive metal clamps M. The space between the two electrodes is bridged by a conducting path of coke A, which constitutes the distinct core of the furnace, and relegates it to the class of which Borchers's furnace is a typical example. This core is packed round with the raw material N, consisting of coke, sand, sawdust, and common salt. The process of conversion is said to be far from economical.

A resistance furnace, based upon the fundamental principle of the Nernst lamp, has been devised by Doctors Nernst and Glaser. The resistance, or heater, is cylindrical, electrical connection with it at the top and bottom being secured by an annular packing of some conducting oxide held in place by iron clamps and bolts. The hollow cylinder is surrounded by a jacket of oxide loosely packed between it and an outer cylindrical sheath, an arrangement which prevents undue waste of heat. The heating cylinder, which consists of a mixture of magnesia, calcium carbonate, alumina, and silica, is closed by a lid, and the substance to be treated is either packed directly into it or contained in a crucible located within it. In the former case the cylinder is protected internally by an additional lining of pure magnesia, coated with graphite to give it an initial conductivity.

The Cowles furnace, again, is typical of that class of resistance furnace in which the path of high resistance consists of the material to be treated and does not form part of the furnace proper. The Cowles furnace first made its appearance in 1884, and takes several forms, all more or less similar in general principle, but differing in such details as affect the class of work for which they are intended.

In its simplest form it consists of an oblong fire-brick structure, provided with a lid, in which are one or more vent holes to permit the escape of the gases generated. Massive carbon electrodes are introduced horizontally through the two ends of the furnace, electrical connection with them being secured, in an early form, by a species of tubular gland through which each electrode passed and which was filled with copper shot. In passing to and fro through these glands the carbon rods set up a kind of rolling friction with the shot, and fairly good electrical contact was thus established between them.

A preliminary lining of granular charcoal was given to the furnace, which, being a bad conductor of heat, prevented undue loss due from radiation and diffusion. Inside this lining, again, was packed the partially conducting mass to be heated, forming a chain between the two carbon electrodes. When the current was turned on this mass became heated by the passage of the current through it, after the manner of the carbon filament in the ordinary incandescent lamp.

In a later form (fig. 10) of the Cowles furnace charging funnels F F were introduced through apertures in the lid, while the hearth sloped from either end to the center, at the lowest point of which was provided an outlet *o* for drawing off the molten products. C C are the carbon electrodes; G, the glands containing the shot; and *c*, the lining of non-conducting charcoal. The funnels F, by a judicious feeding process, provided a means of keeping the resistance of the column of material fairly uniform at all points, thus insuring an even distribution of heat throughout the mass.

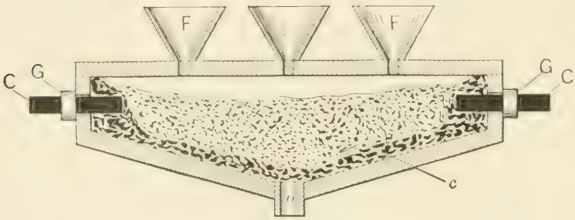


FIG. 10.

The Cowles furnace for the treatment of zinc ores was also of the resistance type, and is represented by fig. 11, where R is a long cylinder of fire clay, mounted in a brickwork setting and surrounded by a jacket of some refractory material J, which is also a bad conductor of heat. The inner end of the cylinder R is effectually closed by a flanged disk of carbon C, which also constitutes one electrode of the furnace, the other taking the form of a plumbago crucible P, the convex base of which fits into the outer extremity of the cylinder R and forms a removable seal. Further, by way of an aperture *a* in the wall of the crucible, the metallic zinc passes over into it by distillation and is collected therein, a chimney or outlet *c* serving to carry off the gases and fumes produced. The charge of broken zinc ore is, as before, spread evenly along the cylinder, so as to form a semiconducting chain between the two electrodes.

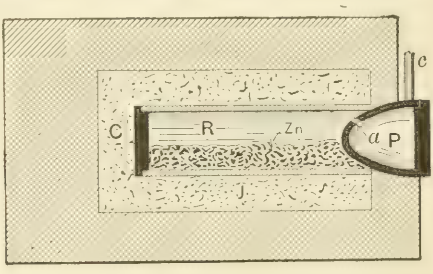


FIG. 11.

The Cowles furnace for the manufacture of aluminum alloys partook of the nature of Borchers's furnace, although it had not, strictly speaking, a continuous resistance core of its own. Two massive tubular electrodes, provided with a means for manual adjustment, carried close-fitting cores of smaller section, which inclined to one another and actually met, forming a conducting core of high resistance at a point in the center of the furnace immediately under the aperture of the feeding hopper. These smaller electrodes, together with the raw material fed on to them at the point of meeting, formed a conducting link of high resistance between the main electrodes, and the heating effect of the current was thus localized and confined to the point at which it was most needed, namely, at the feeding center of the cavity.

A circular form of resistance furnace, devised by M. R. Conley

and intended mainly for the reduction of iron ores or the manufacture of steel, consists of a cylindrical fire-brick structure, the inner wall of which is contracted to form a narrow opening at about two-thirds of its depth to the hearth proper, which lies below. At the contraction is introduced a circular set of electrodes of segmental form, made of the usual compressed carbon mixture, and isolated from one another by intervening segments or pillars of fire brick.

The electrode segments constitute an even number, and are connected alternately to the positive and negative poles of the source of current. Means of adjustment are provided which allow the segments to be fed radially as they wear away. A similar circle of segmental electrodes surrounds the central portion of the furnace proper, or crucible, which is located below the contraction and provided with an outlet for drawing off the molten metal as it forms. By a suitable manipulation of the current and connections to the furnace it is possible with this device to secure a combination of heated zones or paths through the mass of material under treatment, the position of which can be varied at will, so as to penetrate to all parts and secure a homogeneous and uniform fusion.

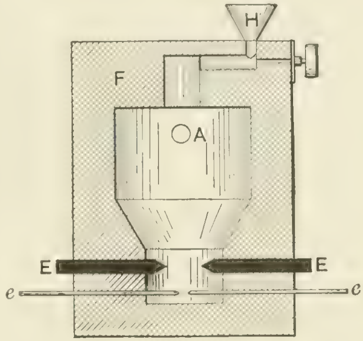


FIG. 12.

The Readman-Parker furnace for the manufacture of phosphorus was invented independently by these two gentlemen in 1888, and they subsequently combined their ideas to form a community of interests. It consists of the usual fire-brick structure F, fig. 12, and feeding hopper H, the furnace being hermetically sealed in order to exclude atmospheric air. A discharge flue A carries off the gases and vapors formed during the process, and the interior of the chamber is contracted at its lower portion, as shown, to form a hearth. Mutiple electrodes E E are employed, facing one another in two rows, passing through the side walls of the structure, while smaller electrodes *e e*, below them, which can be brought into closer proximity, are employed to start the current flow. These are subsequently withdrawn, and the action, which resembles that of a resistance furnace with a conducting path formed of the material under treatment, is maintained between the main electrodes E E.

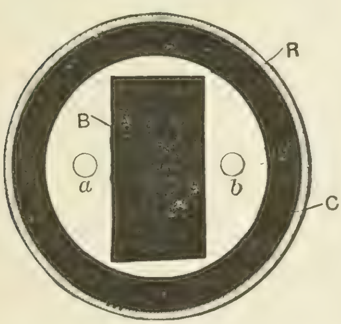


FIG. 13.

The ingot carbide furnace recently patented by Mr. Parker should have a decided future before it. The principle of its construction is represented in sectional plan in fig. 13, in which R is a cylindrical

retort or crucible lined throughout with carbon C, forming one electrode, the other being a massive carbon block of rectangular section B, which is supported at the center of the retort, and is of such dimensions that its corners approach very closely to the inner carbon walls of that vessel. The raw material is fed in at hoppers on either side of B, their position being indicated by the circles *a* and *b*. While working the crucible and its contents revolve, thus constantly bringing fresh portions of the mass within the zone of activity, while by a carefully proportioned train of gearing the electrode B is gradually raised at such a rate that its lower extremity is always immersed at a constant depth in the mass under treatment, while an ingot of finished carbide is gradually built up beneath it in the crucible.

A series of patents have been recently granted in the United States on electric furnaces for the manufacture of such comminuted products as pigments, abrasives, oxides, refined metals, and a miscellaneous collection of similar character. The general arrangement consists of an arc or resistance furnace, with which is combined an air blast device, playing either immediately onto the furnace contents or upon the vapors arising from it. An example will serve to demonstrate the general principle involved.

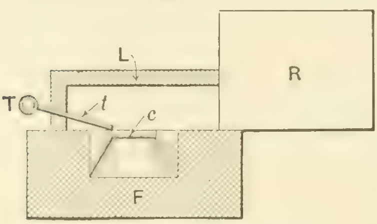


FIG. 14.

Fig. 14 represents a furnace of this description, devised by C. S. Lomax and patented as recently as March, 1902. It is intended for the manufacture of the various commercial oxides of lead and tin. A refractory block F has a narrow channel *c* cut in its upper surface; this constitutes the hearth of the furnace, and is of uniform cross section for about the center third of its length. At each extremity it merges into a deeper and wider wedge-shaped cavity, in either of which is placed, vertically, an electrode; T is a main, supplying cold or heated air to the discharge jets *t t*, which are set at such an angle that the air emerging from them is projected downward into the central trough or channel; L is a cover or screen which collects the products and guides them into the chamber R.

The mode of procedure is exceedingly simple. The channel *c*, together with its enlarged ends, is filled with the molten lead or tin to be converted; the current is turned on, and that portion of the molten column bounded by the narrow central channel immediately attains a considerable temperature, owing to its smaller cross section. When the required heat has been reached the air blast is brought into play, causing the finely divided metallic particles to combine with its oxygen, the resulting compound being carried over into the chamber R. This form of furnace is adaptable to making a variety of oxides, the necessary changes in chemical combination being brought about by varying the respective temperatures of the air blast and the molten metal.

Ruthenburg's electro-magnetic furnace is another practical example of the proverb "Necessity is the mother of invention." One of the purest sources for the extraction of metallic iron is "iron sand" and similar ores, the process of treating which has hitherto been hampered by their finely divided state and consequent clogging of the smelting furnaces. Ruthenburg's invention has in view the preliminary agglomeration of this sand, with the object of thus converting it into a form more suitable for the ordinary operation of smelting.

His furnace is represented in fig. 15, and consists of two similar cast-iron hoppers H H, hinged together at the point of support *a*, and into which the iron sand is fed at equal rates. The discharge orifices *o o* are opposite to each other, and the distance between them can be varied at will by the handwheel and worm W. The two hoppers constitute the electrodes, terminal connection with them being secured as shown at *t t*, where the discharge nozzles are also water jacketed; C C are magnetizing coils encircling the hoppers and having their windings connected either in series with or in shunt across the hoppers. Their office is to magnetize the individual particles of the sand, causing them to adhere together temporarily, and thus assist in forming a self-supporting mass M across the discharge apertures. This mass is subjected to the maximum heating effect, and the semimolten product drops away into the crucible R, placed to receive it.

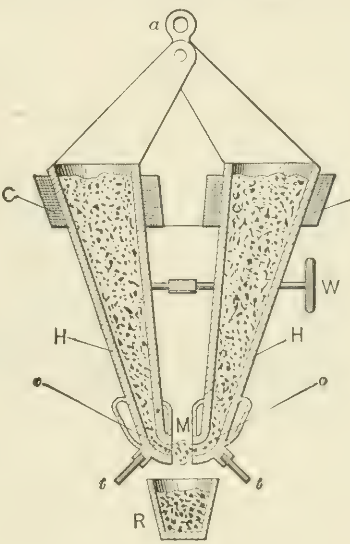


FIG. 15.

A novel type of resistance furnace, patented independently, with some slight variation of detail, by Colby, Ferranti, and Kjellin, is worked on the inductive principle, and consists of an annular or helical channel in a refractory base, filled with a conducting or semiconducting medium, which constitutes the furnace charge, and has a heavy current induced in it by a surrounding coil of many turns, carrying an alternating current. The device, in point of fact, acts as the closed circuit secondary of a step-down transformer, and is said to be admirably adapted for the fusing of such metals as platinum, which, if exposed to the atmosphere during the process, as in the ordinary type of furnace, occlude oxygen and other gases in their mass, which lead subsequently to blowholes and other imperfections in the casting. The Kjellin furnace principle has recently been applied to the manufacture of steel at Gysinge, Sweden, with great success.

The experience of late years in the construction and use of electric furnaces trends toward the establishment of the resistance furnace as a type more readily capable of efficient regulation. This is further accentuated by the fact that overheating is, to a considerable extent, possible, and, indeed, prevalent in many types of furnace, especially those of the arc variety. Scientists and others unversed in the possibilities of the electric furnace as a source of artificial heat hailed its introduction with delight as a means of overcoming many of the difficulties previously imposed by the limitations of temperature. In so doing they in many cases overlooked the very simple fact that it is possible to have too much of a good thing, and the consequent tendency was to overrate rather than underrate the temperature required for various commercial processes.

Experience, however, has exposed this fallacy, and as a natural result we turn to that type of furnace which offers the best means of regulation and the absence of excessive variation, viz, the resistance furnace.

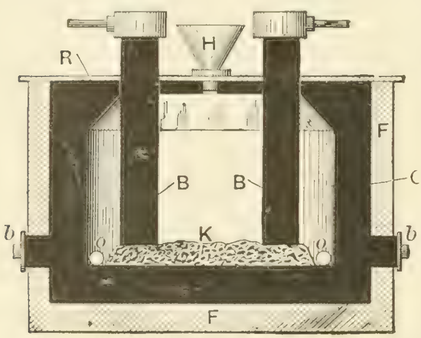


FIG. 16.

Here again we are beset with further difficulties, for if we employ a portion of the charge itself as a high-resistance column, excessive variations creep in, owing to the changeable nature of the column with the reactions taking place within it, whereas if we employ a definite core of small cross section, as in the Borchers class, the capacity of the furnace is limited, and the cost of its upkeep is increased by the very necessary and frequent renewal of the conducting rods.

With a view to minimizing these various drawbacks, Mr. H. I. Irvine, of Niagara Falls, has brought out a resistance furnace in which the heated column consists of a fused electrolyte, maintained in a state of fusion by the passage of the current and communicating its heat by radiation and diffusion to the encircling charge which is packed around it.

The general construction of this furnace, which was mainly designed for the manufacture of phosphorus, is represented in fig. 16. It consists of a refractory structure F, lined with carbon C, and fitted with a domed roof R, in the center of which is a hopper H. Two vertical carbon electrodes B B descend vertically through R to within a short distance of the hearth, whilst a possible variation in the direction of the heating effect is provided by lateral electrodes *b b*, connected with the hearth itself. The action of the furnace is first started through a mass of coke K, which forms a bridge between the electrodes B B, and is subsequently maintained by the fused slag from the furnace charge

which flows down between the electrodes and is maintained at constant level by the overflow outlets *o o*.

As pointed out by Mr. Carl Hering, the fire brick or other refractory lining of all furnaces when heated becomes a conductor after the manner of a Nernst lamp glower. Though unavoidable, this is a contingency which, with furnaces of the resistance type at least, must be taken into account, in that it increases the total conductivity of the device and necessitates a corresponding increase in the working current. He further points out that the heat thus communicated is not lost, except in a small degree, consequent upon the decrease in the thickness of the nonconducting walls and the diminution of their heat-conserving qualities.

Equally important with the selection of an easily regulated and comparatively invariable electric furnace, ranks the question of temperature determination. At the enormous temperatures developed in the electric furnace all previously known methods of temperature measurement, whether by thermometer or pyrometer, desert us, in that the constituent parts of these various apparatuses will not stand the direct application of such terrific heat. Here again stern necessity has been the means of inspiring investigators to action, with a view to discovering some efficient method for the measurement or comparison of these high temperatures.

Fery's suggested method for determining the high temperatures usually encountered in electric furnaces consists in a practical application of Stefan's law, which is to the effect that the radiation of an absolutely black body is proportional to the fourth power of its absolute temperature. Kirchoff has proved that the interior of an inclosure of which the walls are at a uniform temperature is equivalent to an "absolutely black body," i. e., a body which absorbs all the heat imparted to it, giving it out again by radiation, and not by reflection. In this connection, therefore, the interior wall of an electric or other inclosed furnace may be regarded as an absolutely black body, a small aperture in which does not materially affect the conditions governing this definition.

Fery's practical application of this law to the measurement of furnace temperatures consists in a species of telescope with a fluorspar objective. This telescope is placed in line with the aperture in the furnace wall, and, receiving the heat radiated therefrom, concentrates it upon a small thermo-couple. By an inner diaphragm, regulating the number of rays which reach the thermo-couple, the device is rendered independent of its distance from the furnace wall. The fluorspar objective, by its absorption of radiant heat, reduces the sensitiveness of the arrangement by about 10 per cent; but, notwithstanding this, it has proved of extreme utility, owing to its enormous range and its applicability in such cases as those with which we are dealing at the

present moment, where other generally accepted methods are out of the question. The actual temperature is, of course, obtained from a specially prepared table or curve, and is read from the electro-motive force recorded by the thermo-couple.

Another, somewhat crude, method of measuring furnace temperatures, into which the personal element is liable to enter, causing an error of judgment, consists in a telescope, as before, mounted on a convenient stand and placed in line with a small aperture in the furnace wall. Inside the tube of the telescope is located a small incandescent lamp, which can be energized by one or two battery cells, and the current through it, and an ammeter placed in series with it, regulated by a suitable switch and rheostat. The principle upon which its action depends is that which involves the apparent disappearance of the filament when raised to the same degree of incandescence as the furnace lining and viewed against the latter as a background. If the lamp be inactive, the filament appears as a black line; at equal incandescence it becomes invisible, while if its state of incandescence be above that of the furnace it assumes the appearance of a white line. By regulating, therefore, the current through the lamp until the filament apparently disappears, its temperature is made equivalent to that of the furnace, and the result is read on a specially prepared table. The limit of the apparatus is 3,600° F., so that for electric-furnace work its field of utility is somewhat limited.

In the preceding paragraphs the writer has by no means covered the entire field of development of the electric furnace, but has confined himself to a brief description of those examples which serve as a general type of the class to which they, respectively, belong. The subject is a large one, and its comprehensive study would fill a volume of no mean dimensions, while its importance from a chemical and metallurgical point of view must not be underrated.

At the end of the year 1900 the power used in electric furnaces was estimated at 225,000 horsepower, of which 185,000 horsepower were employed in the manufacture of calcium carbide, 27,000 horsepower in the manufacture of aluminum, 11,000 horsepower in that of copper, while carborundum was responsible for the output of some 2,000 horsepower. Any gain, therefore, in the construction or working of electric furnaces, however slight, or apparently worthless, provides food for serious reflection, in that it may be the means of saving large sums of money annually.

HIGH-SPEED ELECTRIC INTERURBAN RAILWAYS.[a]

By George H. Gibson.

The electric railway is to perform a service for mankind as notable and perhaps ultimately as great as that rendered by its steam-operated precursor. Already it handles the bulk of suburban and short-distance interurban passenger traffic; it carries freight, mail, express, and baggage; it operates at speeds reaching 60 miles per hour; its cars are operated on time schedules and dispatched by telephone; its roadbed is often as expensive and heavy of construction as that of the best steam lines; and, what is more interesting to the investor, it pays large dividends. At the present time $1,600,000,000 are nominally invested in electric roads in the United States and upon this sum $7,000,000 are paid in yearly dividends; 300,000 employees receive yearly in wages $250,000,000, and there are 20,000 miles of track on which 60,000 cars are run. In 1899, 10 miles of electric road were built for every mile of steam road constructed.

The greatest development of interurban roads has taken place in the great agricultural districts of the Middle Western States, where they have grown to a truly surprising extent. It is often said that electric railways have checked the concentration of population in great cities by creating suburban districts, but in the farming regions they have had a still greater effect in building up many small centers of population. The Union Traction Company, of Indiana, operates 109 miles of interurban track and 54 miles of city track in the gas belt of that State and serves a population of 350,000. It connects the cities of Anderson, Marion, Muncie, Indianapolis, and about 20 smaller towns, and traverses 6 of the most prosperous counties of the State. The interurban lines are located almost entirely on private right of way, protected by fences and cattle guards. Tests have shown that a maximum speed of 58 miles an hour may be reached and an average speed of 45 miles an hour maintained. Cars are run in each direction every hour, and special cars are furnished for theater parties, excursions, and picnics. The rates of fare are approximately 1 cent a mile. The daily receipts of the interurban lines are said to be $3,000 on an average, but this is frequently increased to $8,000, and on one occasion was $11,000 in a

[a] Reprinted, by permission of the publishers, from The Engineering Magazine, New York and London, Vol. XXIII, No. 6, September, 1902. Some of the illustrations and parts of the original article are here omitted.

single day. Large additions are contemplated about doubling the present mileage. Power is generated in a central station at Anderson, containing three 1,000-kilowatt Westinghouse alternators, and is transmitted by 3-phase alternating current at 14,000 volts to 8 substations, which are supplemented by storage batteries.

One of the greatest possibilities of the interurban road lies in the development of freight traffic. It is well fitted for the transfer of farm produce and supplies for farmers and for carrying package merchandise, and it can often give great convenience of delivery and the possibility of handling freight economically, especially in small cities. The Chicago, Harvard and Lake Geneva Railway has not only a large freight traffic of its own, but carries on an interchange of business with steam roads to a greater extent perhaps than any other electric road in the United States. Its southern terminus is at Harvard, on the Chicago and Northwestern Railway, and at Walworth, $8\frac{1}{2}$ miles north of this place, the road crosses the Chicago, Milwaukee and St. Paul Railway, thence running 2 miles northeast to Lake Geneva, one of Wisconsin's most popular summer resorts. One-third of the business of the road is in handling freight. Freight cars from the railroads are hauled to sidings on the electric road at a flat rate of \$5 per car, and piece freight is transported on a one-rate plan between any two points on the road for 5 cents per 100 pounds, no package being handled for less than 10 cents. A freight motar car with a crew of 2 men carries package freight and hauls from 1 to 4 steam-road freight cars. There are 6 freight sidings along the road, not including the company's yards. Live-stock shipments are an important part of the business. In summer refrigerator cars are run twice a week over the Chicago and Northwestern Railway for the benefit of creameries situated on the electric road, and last winter 3,000 tons of ice were hauled from Lake Geneva for local use along the line. The company receives \$500 per year for hauling mail two trips daily each way. Passenger tickets are sold by the electric road to points on the steam roads and baggage is carried free. The power house is located at Murray and contains two generators of 500 kilowatts each. The equipment consists 10 motor cars and 6 trail cars. The maximum speed is 45 miles per hour.

While many electric roads have been constructed cheaply and of light materials, the tendency is more and more toward a substantial type of construction similar to the best steam-railway practice. The Grand Rapids, Grand Haven and Muskegon Railway, recently completed, is equipped with standard 70-pound T-rails laid on a private right of way. The road runs from Grand Rapids to Muskegon, Mich., a distance of 35 miles, with a branch 7 miles long to Grand Haven. It parallels steam roads to both cities, the running time of the electric and steam cars being about the same. The country is well developed

industrially, containing tin-plate and paper mills, knitting factories, and machine shops. Grand Rapids has a population of 96,000, Muskegon 26,000, and Grand Haven 5,000. The country near Grand Haven is largely occupied as a summer resort by people from Grand Rapids, Chicago, and Milwaukee. In passing through towns and cities the road uses the overhead-trolley system, for which the cars are equipped with a trolley arm, while upon the inclosed right of way through the country the third-rail system is employed. The third rail is discontinued at crossings, the current being carried under the highways by conductors imbedded in pitch in underground conduits. The conductor rail is of 65-pound section and standard composition, and is supported upon reconstructed granite insulators. The power house, located at Fruitport, contains five 250-kilowatt generators, three of which are double-current machines, generating both direct and alternating currents, while two are standard alternators. All are direct-connected to Westinghouse vertical compound engines and are arranged for operation in multiple.

Another interesting road running out from Grand Rapids is the Grand Rapids, Holland and Lake Michigan Rapid Railway, extending from Grand Rapids to Holland and there connecting with two short lines to the lake shore. This road traverses a rich farming country, thickly settled by Dutch and Germans, and the two lines to the lake shore reach a favorite summer-resort district. The aggregate length of track of the combined roads is 71 miles, the total distance covered being 45 miles, 19 miles of this comprising the two roads running from Holland to the lake. * * *

While electric roads are approaching steam lines in type of construction and methods of operation, many of the latter are finding it advantageous to adopt electric traction, especially for short-haul and suburban service. The Quebec, Montmorency and Charlevoix Railway has in this way within two years increased its total yearly capacity and receipts from $44,221 to $73,292. The overhead trolley is used, and the cars are equipped with two 50-horsepower motors and air brakes and are capable of running 45 miles per hour. The total cost of the electrical installation for 30 miles of track, including 6 double-truck cars and a 600-kilowatt alternating-current generating station, was $169,375. On Sundays and holidays the road is used so extensively that its resources are fully taxed, and it has been found necessary to increase the rolling stock so that, in addition to the regular cars, specials may be run at ten and fifteen minute intervals. It will further be necessary to construct a double track between Quebec and Montmorency. In addition to the electric traffic, steam, freight, and special pilgrimage trains are constantly handled, and no collision or other accident has so far occurred.

Another road which has greatly improved its service by adopting electric traction is the Buffalo and Lockport Railway. The company operating this road was organized in April, 1898, and leased for ninety-nine years the Lockport Branch of the Erie Railroad, running from Lockport to North Tonawanda, N. Y., and comprising 13½ miles of single track. It has since bought 5½ miles of road in the streets of Lockport, 7½ miles of single track between Buffalo and North Tonawanda, and a mile of track in Buffalo, making the total length of the line at present 29 miles and giving through service from Buffalo to Lockport and Niagara Falls. Power is obtained from the Niagara Falls Power Company, and is transmitted at 10,500 volts to a rotary converter substation located at Lockport, from which it is fed as direct current at 1,500 volts to the trolley wires. * * *

A number of roads used chiefly for pleasure riding have been built in southern California, in the neighborhood of Los Angeles. The population is composed largely of wealthy people, who have sought that part of the country on account of climatic conditions and who patronize the roads liberally. One of the roads from Los Angeles extends to Pasadena, and from there to Echo Mountain and Mount Lowe. Another line runs from Los Angeles to Santa Monica, on the Pacific Ocean. The Los Angeles-Pasadena line was so well patronized the first year that it was necessary to double-track the road. It competes with three steam lines, and one of the latter has been compelled to reduce its train service by half, and would reduce it still further if that were not prevented by its franchise. The cars on the Pasadena line are each equipped with two 40-horsepower motors and Standard air brakes, and make a maximum speed of 25 miles per hour. The road to Santa Monica has quadruple equipments of 50-horsepower motors and can maintain a speed of 40 miles per hour. Another road which is being built from Los Angeles 20 miles to Long Beach will have as one of its features a broad boulevard, 184 feet wide, on each side of the track.

Perhaps the field of greatest activity in the United States for the construction of high-speed interurban lines has been in northern Ohio and southern Michigan, where there is now a network of highly equipped roads upon which through traffic is being established, offering even such accommodations as parlor and sleeping cars. It is said that a service of this character will shortly be established between Columbus and Cincinnati. The roads utilized will be the Southern Traction Company's lines from Cincinnati to Dayton; the Dayton-Springfield and Urbana to Springfield; and the Columbus, London and Springfield to Columbus, the service to be established as soon as the latter road is completed. The schedule time between Columbus and Cincinnati will be about six hours. It is also proposed to operate through cars between Cleveland and Cincinnati, the route from Cleve-

land being over the Cleveland, Elyria and Western, the Cleveland, Ashland and Mansfield, the Mansfield, Galion and Crestline, and the Columbus, Delaware and Marion, roads all either in operation or under construction.

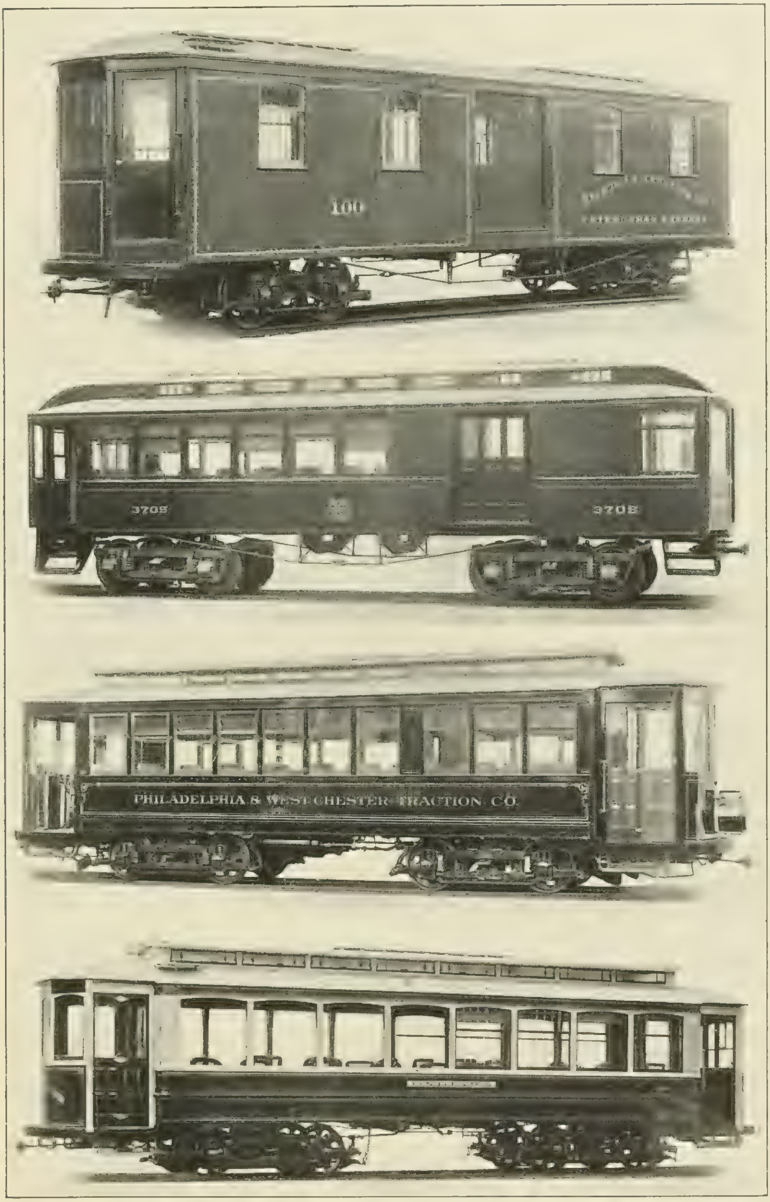
A few notes regarding the Cleveland, Elyria and Western may be of interest, since its power house will be the first railway power station in the United States to be equipped with steam turbines. Two Westinghouse turbines, running at 1,500 revolutions per minute, are to be direct-connected to two 1,000 kilowatt, 2-pole generators, delivering alternating current at 400 volts and 25 cycles per second. Steam will be supplied to the turbines at 150-pounds pressure and 200-degrees superheat, and the exhaust will be under a 28-inch vacuum. The steam consumption is guaranteed not to exceed 10.8 pounds of steam per horsepower-hour; and at one-half load the steam consumption per horsepower is not to increase more than 15 per cent. These turbines are somewhat novel in construction in that the steam is expanded consecutively in two chambers—that is, the steam first passes through a high-pressure cylinder, then through a reheater, and finally through a low-pressure cylinder. The rotating parts of both the high and low pressure cylinders are upon one shaft, the bearing being placed between the two cylinders. Full load may be carried without superheat or vacuum. The adoption of steam turbines has increased the possible capacity with the space available in the existing powerhouse from 2,000 to 5,000 kilowatts. Two 300-kilowatt rotary converters are being installed as connecting links between the present direct-current plant and the alternating-current apparatus. The power is transmitted to substations along the road by alternating current at 20,000 volts.

Cleveland is the center of an extensive interurban electric-railway system, extending in one direction nearly to Buffalo, N. Y., and in the other to Toledo, Ohio, which is also the terminus of a large number of roads. One of the roads connecting Cleveland and Toledo is the Toledo, Fremont and Norwalk, about 60 miles in length and controlled by the Lake Shore Electric Company. The powerhouse at Fremont, about the middle of the line, contains four alternating-current generators, direct-connected to 1,750-horsepower Westinghouse steam engines. Current is transmitted at 16,000 volts to six substations, which are combined with passenger and freight stations in order to cut down the cost of attendance. The high-tension transmission wires are carried upon the poles supporting the trolly brackets. The roadbed, partly upon private right of way and partly upon public turnpike, is constructed for speeds exceeding 40 miles per hour. In preparing for a through service between Cleveland and Toledo, a series of experiments are being made by the Lake Shore Electric Company with a view of determining the most desirable motors for the traffic. A cross-country schedule of 35 to 40 miles per hour has been established

and a speed of over 60 miles per hour has been maintained for short distances. Some of the cars are fitted with four 100-horsepower electric motors. The cars now in service on the Toledo, Fremont and Norwalk are equipped with 75-horsepower Westinghouse motors. That part of the Lake Shore Electric Company's line between Cleveland and Norwalk is entirely on private right of way and is rock ballasted and laid with 75-pound T-rails. This company is making an especial effort to develop freight traffic in fruit and dairy products. Passenger mileage books are sold for $12.50 per 1,000 miles, and local fares are about one-half of those charged by steam roads.

Toledo and Detroit are connected by a series of electric roads, one of the most completely equipped of which is the Toledo and Monroe Railway, having 18 miles of single track laid with 70-pound T-rails and ballasted with broken limestone. The equipment consists of ordinary passenger cars, chair cars, combined passenger and baggage cars, and freight cars. The passenger cars are 40 feet long and a regular schedule speed of 30 miles per hour, including stops, is maintained. The powerhouse contains two 400-kilowatt Westinghouse 3-phase alternators, and a substation contains a 200-kilowatt rotary converter. The long distance transmission is at 15,000 volts, the wires being carried on 45-foot pine poles set 6 feet in the ground and surrounded by concrete, so that no guy wires are necessary. The same poles support the double trolley wire.

One of the oldest high-speed roads in America is the Detroit, Ypsilanti and Ann Arbor Railway. As originally constructed this road had a length of 50 miles, 40 miles between Detroit and Ann Arbor, with a branch line of 10 miles to Saline. The line has recently been considerably extended, now reaching to Jackson, Mich., where it connects with other interurban roads. It is composed of single track throughout. The equipment consists of 20 cars, each provided with four 50-horsepower motors and quick-acting air brakes. The motors can all be thrown in series for slow speed through cities. A regular half-hour service is maintained, with an occasional fifteen-minute service, and all cars are dispatched by telephone, telephone stations being located at turn-outs. The most remarkable effect of this road has been the development of an enormous passenger traffic. During the first year 4,000 passengers were carried per day, against 200 previously carried per day by the steam road passing through the same towns. The fare for 40 miles is 50 cents, while the fare charged by the steam roads for the same distance is $1.12. A 1,000-mile mileage book is sold for 1 cent per mile. The average fare per passenger is 15.9 cents. Many houses are being built in the small towns along the route and market gardening is rapidly developing in the country traversed. Freight service is given twice a day and express packages are



TYPES OF MODERN AMERICAN CARS FOR HEAVY ELECTRIC-RAILWAY SERVICE.

At the top is a 40-foot express car, weighing 25,000 pounds, open from end to end for load; diagonal doors to take in long pieces; speed, 33 miles. Next comes a 40-foot trolley car with baggage compartment, Providence and Fall River branch of New York, New Haven and Hartford Railroad; weighs 45,000 pounds; seats 28 passengers. Below that is a 41-foot 25,000 pound car with 9-foot smoking compartment, intended for average speed of 20 miles. At the bottom is a semiconvertible parlor trolley car for the Buffalo railway, 41 feet 8 inches long, 31,000 pounds. All by the J. G. Brill Company.

FIG. 1.—LOCOMOTIVE FOR THE BUFFALO AND LOCKPORT RAILWAY, GENERAL ELECTRIC COMPANY.

FIG. 2.—MAP SHOWING (BY HEAVY LINES) THE DEVELOPMENT OF ELECTRIC RAILWAYS ABOUT CLEVELAND, OHIO.

carried in the baggage compartments of the passenger cars. When the line was first opened, more freight was offered than could be carried, although the rates were two-thirds more than those asked by the steam-railroad company.

Extending north from Detroit 73 miles to Port Huron, Mich., and comprising in all 110 miles of single track exclusive of sidings, are the lines of the Rapid Railway Company, another early pioneer in the electric interurban railway field. This road is an excellent illustration of the great advances in the building of electric roads made possible by high-tension power transmission. All power is generated at a main station at New Baltimore and transmitted in either direction by alternating currents at 16,500 volts. The power house is equipped with all the latest improvements in the way of coal and ash handling machinery, mechanical draft, economizers, etc., and contains three 1,000-horsepower Westinghouse steam engines, all direct-connected to 3-phase generators. There are five rotary-converter substations—two north of, two south of, and one at the power house. This railway passes through a rich agricultural country and at its middle part through a noted summer-resort district, which is rapidly being built up in consequence of the transportation facilities furnished by the electric line. About the same fares are charged as upon the Detroit, Ypsilanti and Ann Arbor road, and arrangements have been made for an extensive freight traffic in fruit, fish, vegetables, groceries, and general merchandise. It is said that 50 per cent of the lighter trade going to Detroit is now carried by the electric road. The cars are run on train dispatchers' orders, telephone stations being placed at all sidings. After leaving the city limits of Detroit there are no grade crossings, and the track is thoroughly well laid and ballasted. One of the branches of the road closely follows the shore of Lake St. Clair, and the northern part of the road follows the St. Clair River, passing through many fishing, hunting, and boating resorts. Hourly service is given regularly over the whole line, and cars are operated at shorter intervals between points where traffic is dense. The schedule time for the cars is 27 miles per hour, including stops, and between stations the speed reaches 45 miles per hour. * * *

In the State of Michigan there are 24 interurban lines actually in operation, and franchises have been asked for 47 more. The great activity in building electric roads in this territory is due, perhaps more than to anything else, to the fact that it was here that a number of the earliest and most successful roads in the country were constructed, thus bringing the possibilities of electric traction before the eyes of business men and capitalists.

While the Middle West has been the scene of the most active electric railway building in the United States, considerable progress has been

made in some of the more thickly populated Eastern States. At Hudson, N. Y., begins a long electric railway system which extends a distance of 105 miles to Warrensburg, near Lake George, running for a great part of the way along the Hudson and through a semimountainous country and giving a view of the Catskills and the Berkshire Hills. The first 37 miles is covered by the Albany and Hudson Railway, a small part of which is operated by trolley and the remainder by the third-rail system. Except through city streets, the company owns its own right of way, which is fenced in and laid in a very substantial manner. Both running and conductor rails are of T section and weigh 80 pounds to the yard, the third rail being somewhat lower in carbon than the service rails in order to reduce the electrical resistance. The track has been heavily ballasted and the ties are laid 2 feet center to center, every fifth tie being extended to support the third-rail insulators. The latter are supported 6 inches above the tie and are made of wooden blocks, topped by malleable cast-iron caps or chairs. At all highways and farm crossings the third rail is interrupted, but the continuity of the circuit is not broken. Power is supplied from a hydraulic plant at Stuyvesant Falls, on Kinderhook Creek, about 10 miles north of Hudson, and is transmitted by 3-phase current at 12,000 volts to three substations along the line, where it is transformed to direct current at 600 volts. * * *

In view of the high-speed experiments with 3-phase motors that have recently been carried on in Germany, it is gratifying to note that similar experiments with direct-current motors are shortly to be made in America. The Aurora, Elgin and Chicago Railway has been designed for a continuous maximum speed of 70 miles per hour, and the track is of such substantial character and easy alignment that higher speeds can be attained. The service rails are to weigh 80 pounds to the yard, the track is to be rock ballasted, and all bridges will be of concrete and steel construction. The third rail is to weigh 100 pounds to the yard and is to be supplied with direct current from substations, to which power will be transmitted at 26,000 volts by 3-phase alternating current over aluminum feeders. The schedule speed will be 40 miles per hour, including stops at stations 3 miles apart. Cars are to weigh 40 tons, and are to run at a maximum speed of 65 miles per hour, with a possible 70 miles per hour on a level track and with normal voltage on the third rail. The cars are to be operated either singly or in trains and are to be equipped by the General Electric Company.

This paper might seem unduly partial if no mention were made of European roads. However, of high-speed interurban roads in Europe there are extremely few. In Great Britain it can truthfully be said there are no high-speed electric roads at all. The difference between America and Europe with respect to the development of electric traction is very strikingly shown by the following figures: The miles of

electrically operated railways are, in the whole world outside of the United States, 4.64 per million people; in Germany, the highest of continental countries, 41.8 miles; and in the United States, 276.2 miles. It is said that the new plant of the Manhattan Elevated Railway Company, of New York City, which will have a total power of 40,000 kilowatts, equals in capacity the total electric power available for traction purposes in France. The United States has 76 per cent of all the electricity available in the world for traction, 76½ per cent of the electric-railway mileage, and 83½ per cent of all the trolley cars.

A German steam road upon which electric traction has been tried is the Wannsee line, between Berlin and Zehlendorf. Since August, 1900, an electric train has been interspersed in the regular service, a speed of about 25 miles per hour being maintained. The train weighs 193 tons empty and 220 tons loaded, and is composed of ten coaches, the first and last having three motors each, of an aggregate capacity of 975 horsepower. It runs 225 miles per day, the maximum speed being 31 miles per hour. Direct current is used at 750 volts. The efficiency of the power transmission between switchboard and axle was found to be from 70 per cent to 85 per cent. The Government railroad authorities have decided to discontinue the electric service, but the failure of the road has been due more to half-hearted measures than to any defect in the system.

The first installation of a high-speed electric road in Europe was between Düsseldorf and Krefeld, a total distance of 13.6 miles, the longest stretch between stopping places being 10.4 miles. Since the road parallels the steam railway for the greater part of its length, it is considered necessary to maintain a speed of 25 miles per hour on the open stretches. A speed of 37.2 miles per hour has been reached on trial trips. (Pl. IV.) The road does not pass through the intervening towns, but only touches the outskirts. It it double-tracked from Düsseldorf to Oberkassel, the terminus of the Düsseldorf local traffic. Direct current is used at 600 volts pressure, and the cars are mounted upon double trucks, each truck carrying a 40-horsepower motor. The passengers are divided into three classes, the total seating capacity of a car being 34. Three kinds of brakes are used—viz., hand brakes, electric short-circuit brakes, and Standard air-brakes—and each motor car is also equipped with two trolley poles. Trains leave each terminal station every half hour. The road has developed a quite considerable freight and farm service.

A road which has attracted considerable attention by its novel and unique features is the suspended railway at Elberfeld-Barmen, where the cars are hung from a single rail without any side guards or supports, so that in going around curves the cars may assume an inclined position. (Pl. V, fig. 1.) Of the 8 miles originally planned, only 4½

have been built. The speed of the cars is from $12\frac{1}{2}$ to 14 miles per hour. The switching construction is highly interesting, but is not considered safe and is used only by empty cars.

The Swiss[a] roads are very interesting because of the original engineering methods which they embody. Most of them are mountain roads and are provided with rack rails. They are largely patronized by tourists and charge very high fares. The road starting at Zermatt and ascending the Gornergrat has a maximum grade of 20 per cent and is composed of curves throughout 30 per cent of its total length, which is 5.7 miles. The entire roadbed was cut from solid rock or built upon projections. The rack system is of the Abt type. The locomotives weigh $10\frac{1}{2}$ tons each and are equipped with two motors having an aggregate of 90 horsepower and operating at 500 volts. (Pl. v, fig. 2.) The speed is only $4\frac{1}{3}$ miles per hour, and double-reduction gearing is used. In addition to the two spindle brakes, one operated on the rack wheels and the other on the surface wheels, there is an electric brake which comes into action as soon as the speed of $4\frac{1}{3}$ miles per hour is exceeded. The motors are of the 3-phase induction type with wound rotors and collector rings, and in coasting they may be used as extra brakes by inserting resistance in the rotor circuit.

The longest (25 miles) Swiss 3-phase railway is the Burgdorf-Thun road, opened in 1899. The standard trains weigh 56 tons and have a maximum speed of $22\frac{1}{2}$ miles per hour. Current is transmitted at 16,000 volts, which is stepped down, by means of transformers located at an average of 2 miles apart, to 750 volts for distribution to the trolley line. The cars carry four trolleys, two at each end of the car. The equipment consists of two 2-axle locomotives and six 4-axle motor cars, with a number of trailers for passenger and freight traffic. The total power of the locomotives is 300 horsepower. A small transformer is installed on each locomotive or motor car for lighting, heating, and driving an air compressor, Westinghouse air brakes being used. At present only five trains are operated on the line at any time. The fare for the entire 25 miles is 40 and 60 cents for the two classes.

The Stansstad-Engelberg Electric Railway has a total length of 13.8 miles, of which about 1 mile is rack construction. Three-phase current is supplied to the trolley line at 750 volts, at which voltage most of it is generated. The trolley line is protected by Westinghouse lightning arresters. The rolling stock consists of three locomotives and seven motor cars weighing 14 tons and seating 46 persons. (Pl. v, fig. 3.)

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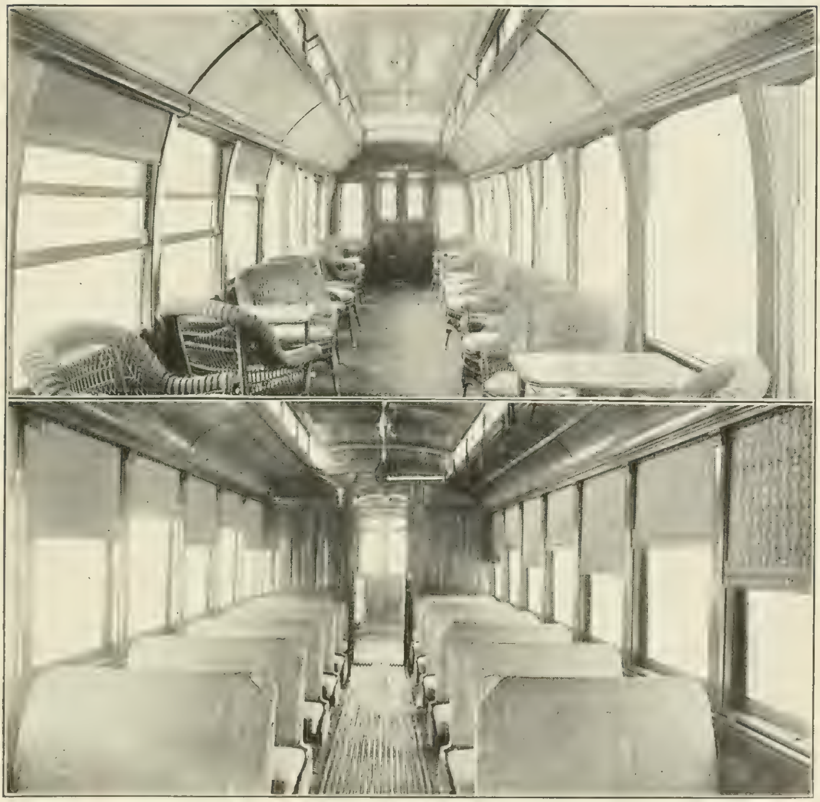
[a] The important electric installations of Italy were reviewed at some length by Signor Enrico Bignami in The Engineering Magazine for November, 1900. For this reason they are omitted from Mr. Gibson's summary.—The Editors.



INTERIORS OF ADVANCED-TYPE TROLLEY CARS.

The car above is the "Ondiara," shown in exterior view at the bottom of Pl. I. Below is a 46-foot 35,000 pound car for the Chicago and Joliet Railway. It has a 14-foot smoking compartment and toilet room against the partition. Maximum speed 70 miles per hour.

DÜSSELDORF-KREFELD ROAD WITH CARS WHICH RUN AT 60 KILOMETERS PER HOUR.

Perhaps the most remarkable of the Swiss railways is the Jungfrau line, which runs for 1¼ miles along the base of the mountain and then ascends by means of a tunnel 6⅓ miles long to an altitude of 13,435 feet. After leaving the terminal station, the passengers are raised a further 240 feet by an elevator. The grade is 25 per cent along the entire road, with the exception of a 2.2-mile section which has 67 per cent grade. The rolling stock consists of five locomotives, ten passenger cars, and two freight cars. The locomotives in reality form the rear truck of the cars, but can only be used without the latter. Three independent brakes insure safety during the descent. The locomotives are equipped with two 3-phase motors, having a normal capacity of 25 horsepower each, and the speed is 4¾ miles. The forward motor is coupled to a continuous-current dynamo, which serves to exite both motors during the descent, thus turning them into generators. There are but few days when the summit presents a clear view of the surrounding territory, and the traffic is therefore concentrated in a very short time, when the rush is very great, and at such time eight trains per day operate. * * *

[Mr. Gibson's paper concludes with a brief account of the Berlin-Zossen experiments, which are treated in this report by the following article by Doctor Gradenwitz.]

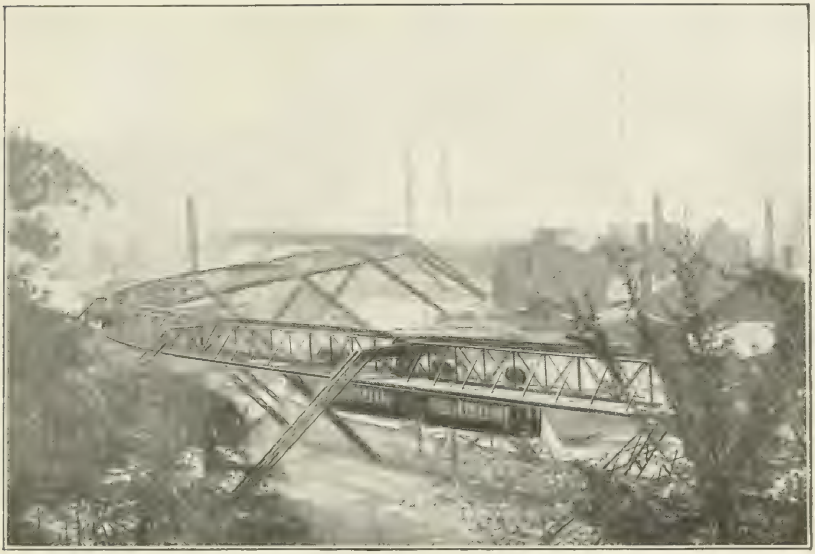


FIG. 1.—SUSPENDED RAILWAY AND TRAIN AT ELBERFELD.

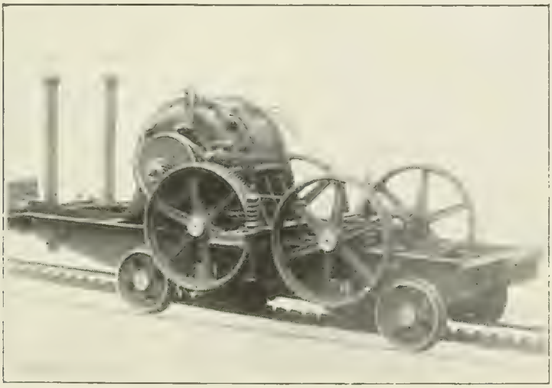


FIG. 2. -TRUCK OF THE GORNERGRAT LOCOMOTIVE.

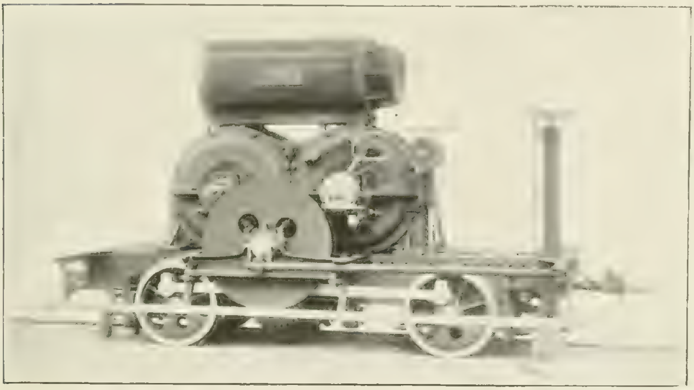


FIG. 3.—STANSSTAD-ENGELBERG ELECTRIC LOCOMOTIVE BEFORE HOUSING.

THE MARIENFELDE-ZOSSEN HIGH-SPEED ELECTRIC RAILWAY TRIALS.[a]

By Dr. ALFRED GRADENWITZ.

The Marienfelde-Zossen high-speed electric-railway trials, as is known, were undertaken with a view to obtaining the necessary technical and economical data for a regular electric-railway service up to speeds as high as 200 kilometers per hour. Useful data were available from previous trials made by the Siemens & Halske Company on their special experimental line in Gross-Lichterfelde, near Berlin, which line was intended to be a model railway for operation by 10,000-volt currents. It is due mainly to the enterprise of the two leading electric firms in Germany, the Siemens & Halske Company and the Allgemeine Elektrizitäts Gesellschaft,[b] as well as to the assistance of the most important German banking firms and the authorities concerned, that as early as the fall of 1899 a special concern was formed under the name "Studiengesellschaft für Elektrische Schnellbahnen." The German railway authorities placed at the disposal of the undertaking the Marienfelde-Zossen military railway, and two cars to be constructed respectively by the firms mentioned above were to be used for the experiments.

The Siemens & Halske Company undertook the construction of the line supplying the electric power, whereas the Allgemeine Elektrizitäts Gesellschaft were willing to generate the power in their Ober Schönweide electricity works as well as to construct the feeding wires thence to Marienfelde-Zossen. The line was to be constructed after the model of the Gross-Lichterfelde experimental track, and the same arrangement of the conductors and collectors, as well as the same kind of current, namely, 10,000 volts rotary current between two conductors, was to be used.

The Marienfelde-Zossen military line, 23 kilometers in length, seemed specially available, as there are no curves of less than 2,000 meters radius, the short gradients being not more than 1:200. The permanent way, however, corresponded only with the older types of

[a] Reprinted, by permission of the publishers, from the Engineering Magazine, New York and London, Vol. XXVI, No. 4, January, 1904. Some illustrations of original article are here omitted.

[b] Familiarly known by the convenient abbreviation "A. E. G."

Prussian railways, consisting of light rails of 33.4 kilograms per meter (67 pounds per yard), placed partly on wooden sleepers and partly on short iron sleepers, the roadbed consisting mainly of inferior material. Though it accordingly was anticipated at the very outset that the existing permanent way would not be sufficiently resistant for maximum speeds as high as 200 kilometers per hour, it was decided to begin the trials without any rebuilding of the track, apart from some immaterial improvements. After the number of sleepers had been somewhat increased, and the roadbed reenforced with considerable amounts of broken stone, the track stood perfectly well the strain involved by speeds up to 130 kilometers (80.8 miles) per hour. As, however, in connection with the experiments made in the fall of 1901, serious troubles were experienced for the maximum speeds of 140 to 160 kilometers per hour, a thorough rebuilding of the track was eventually carried out in the course of the summer of 1902. The new rails have a weight of 42 kilograms per meter (about 84½ pounds per yard) and a length of 12 meters, being placed on 18 fir sleepers with hard-wood pegs; 15,000 cubic meters broken basalt were used for the roadbed. About 17 kilometers of the track were fitted with guard rails such as used in connection with ordinary railways on bridges, etc. These guard rails, the foot of which is 50 millimeters distant from the main rail, are fixed on cast-iron beds, screwed to every sleeper, this arrangement, in addition to preventing derailments, imparting an extraordinary strength to the whole of the roadbed. (Plate I.)

The overhead line.—The arrangement of the overhead line is shown in plates I and II, the middle of the pole being about 2¼ meters distant from the middle of the track and the three horizontal wires conducting the 3-phase current being about 1 meter apart. The whole of the line is divided into sections of about 1 kilometer, each of which is provided in the middle with a device for compensating losses in pressure. The neutral point of the system is connected to the earth and to the rails. The suspension point moves aside somewhat as the collector presses against the horizontal wire, a satisfactory and simultaneous contact between the three horizontal wires and the contact arcs being thus possible. This is insured by having the single parts on the outrigger, intended for carrying the insulators, connected by joints. The horizontal wires have a double insulation against earth, and each insulation separately is susceptible of standing the whole of the maximum pressure of 20,000 volts occurring during the service. The wires have cross sections of 100 square millimeters (0.155 square inch) each, the tension between each two wires varying between 10,000 and 12,000 volts. Hard copper wire with a breaking strength as high as 38 kilograms per square millimeter and a conductivity more than 97 per cent of that of chemically pure copper is used; lightning arresters are provided, as well as safety devices in case of a fracture by which the wire is automatically earthed.

THE MARIENFELDE-ZOSSEN TRACK.

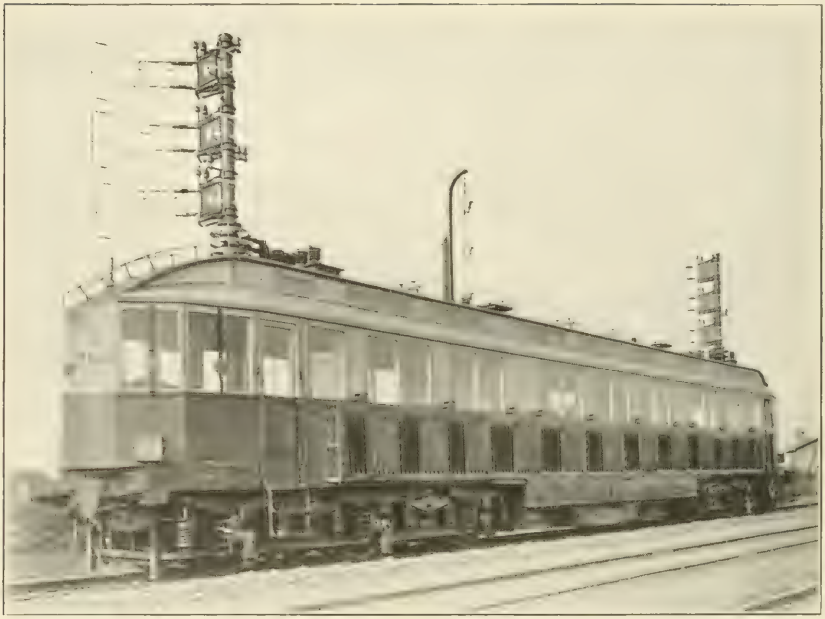


FIG. 1.—THE SIEMENS & HALSKE CAR USED IN THE MARIENFELDE-ZOSSEN EXPERIMENTS.

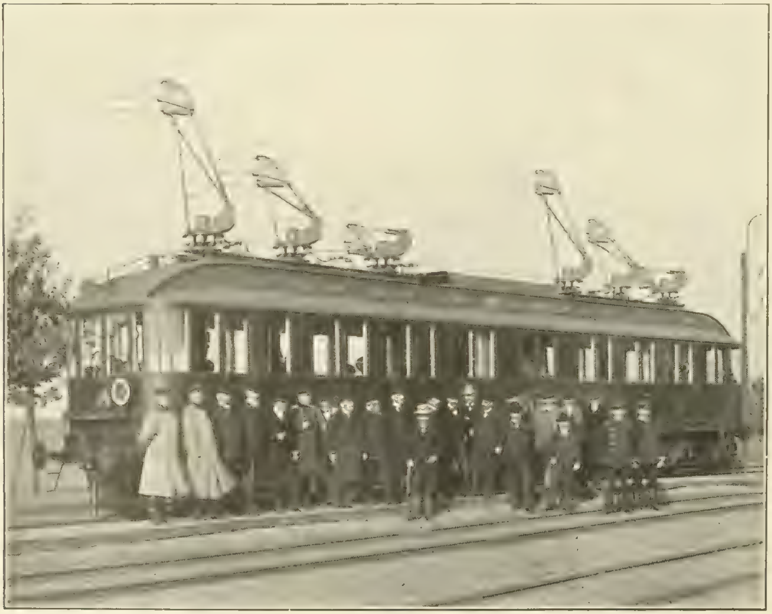


FIG. 2.—THE A. E. G. CAR USED IN THE MARIENFELDE-ZOSSEN HIGH-SPEED RUNS.

View taken immediately after the successful trials on October 28, 1903, when a speed of 210 kilometers (130.5 miles) an hour was attained.

The collectors.—The collectors are constructed according to the system developed by the Siemens & Halske Company on their Gross-Lichterfelde experimental track; they are nearly identical on both cars, differing only as to the details. In the Siemens car they have the form of two masts supported by the cars at either end and movable around their vertical axis. These masts consist of two Mannesmann tubes, each about 200 millimeters in diameter, inserted one into the other. By means of a crank acting on a double-toothed gearing, any desired rotation of the masts may be effected from the motorman's stand. The sliding rings are attached to an insulated tube. Contact springs, screwed by means of hard-rubber insulators on a special flat iron frame, are fixed to the three sliding rings. Into the insulating tubes and partly into the lower part of the collector, the upper tube is slipped, so as to be readily dismounted after loosening a few screws. This tube bears, at central distances of 1 meter each, three rotating axles for the contact bows proper. The wind pressure against the bow on one side of the rotating axle is balanced by means of a vane attached to the other side of the axle. The Allgemeine Elektrizitäts Gesellschaft car is likewise fitted with two groups of three collectors each, one for each phase, which, however, instead of being placed on one common mast, are arranged one behind the other. Both arrangements have so far given full satisfaction, it being impossible to decide which is the more available. Sparking between the overhead wires and the collector bows, as occasionally noted in connection with the earlier experiments, was recently prevented by some slight improvements in the construction of the collectors. One of the most difficult problems, namely, the transmission of high amounts of energy from a stationary conductor to a train running at enormous speeds, has thus been satisfactorily solved.

The motor cars.—The two motor cars used with these trials were constructed by Messrs. Van der Zypen & Charlier, Cologne-Deutz, in accordance with the electric apparatus supplied by the two electric firms. The cars, intended for about 50 passengers, are 21 and 22 meters in length, respectively, and correspond as to their dimensions and equipment with the technical regulations of the Association of German Railway Administrations. The body of the car rests by means of two center bolts on two trucks without any special springs. In addition there are on the frames of each truck four steps limiting the lateral oscillation of the body by bearing part of the weight of the car. Lateral oscillations of the body were moreover observed only for lower speeds, up to 100 kilometers per hour, whereas with higher speeds the run of the cars was perfectly steady, much more so than with ordinary rapid trains. Each of the trucks is fitted with three axles, the external axles bearing the motor, whereas the central ones serve as running axles. The distance between the axles was at the

beginning 3.8 meters; this has been increased up to 5 meters in connection with the recent successful trials. The distance between the centers of each two trucks is 13.3 and 14.3 meters, respectively, and the diameter of the wheel tread 1.25 meters. Two springs are placed against the axle boxes, namely, one plate spring, 1.5 meters in length, above each axle box, these plate springs being in turn maintained at their ends by spiral springs, the tension of which is regulated by means of screws. As the trucks, in connection with the earlier experiments, followed any deviation in the direction of the track, the distance of the wheels, as above said, was increased to 5 meters, and the bearing springs placed so as to be visible and connected with one another by compensating levers. The center bolts, which formerly were rigidly fixed to the lower frame, were in the course of the recent reconstruction provided with lateral pegs fitted with springs, so as to prevent any transmission of the oscillations of the body to the frame.

The connections of the cars.—The connections of the cars are shown in plate III. In the Allgemeine Elektrizitäts Gesellschaft car, the current is led by means of armored cables from the two groups of collectors to the main switch in the machine room and thence by separate conductors to the transformers. The main cut-out switch is operated only after the run is completed, or as an emergency switch in case of disturbances occurring during the run. From the transformers the low-tension conductors lead through the main controller to the motors. The main controller is also placed in the machine room of the car, being easily actuated from each driver's stand through a steering wheel connected by toothed gearing to an axle traversing the whole length of the car. This controller directs the working current to the motors and through the resistances, and permits forward and reverse running, besides providing for the braking of the car by means of reverse current. There is in addition a small controller in the driver's stand, conveying low-tension current from the transformer to the motor for operating the air compressor in connection with the compressed-air brake.

The connections in the Siemens & Halske car are somewhat different, the high-tension current being first conveyed to one of the two main switches for forward and backward running, which may be controlled from the driver's stand, and thence to the two large transformers, whence the working current is again conveyed through individual switches toward the motors and the resistances. From the main conductors on the roof of the car, part of the current is in addition branched off toward the small transformer placed above the motorman's stand, and conveyed to the electric motor operating the two air pumps. Two special cranks are provided in the motorman's stand for actuating the reversing switch and the motor switch, respectively, the working resistances being controlled by the driver through a special controlling

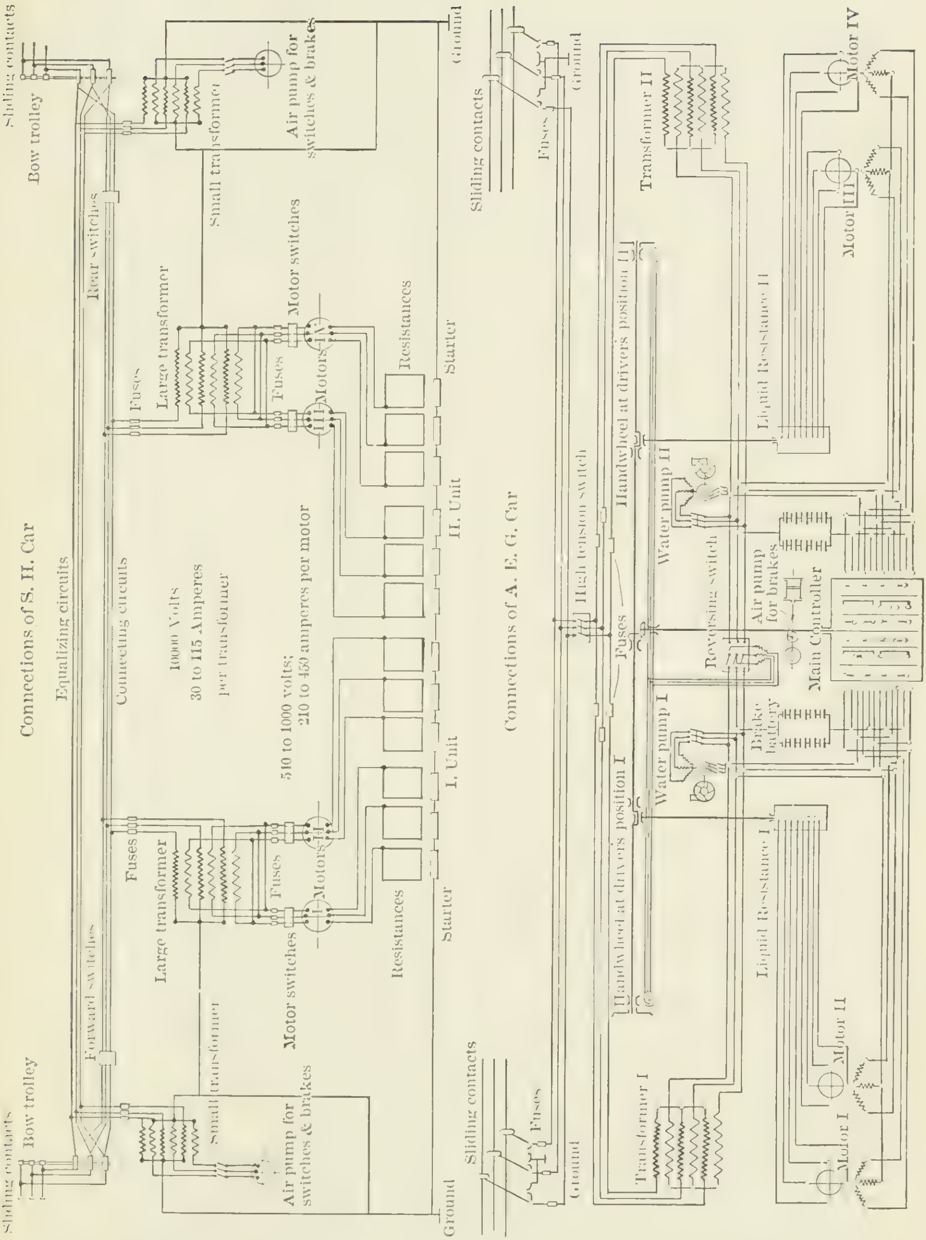


DIAGRAM SHOWING THE CONNECTIONS OF THE SIEMENS & HALSKE AND THE A. E. G. CARS, RESPECTIVELY.

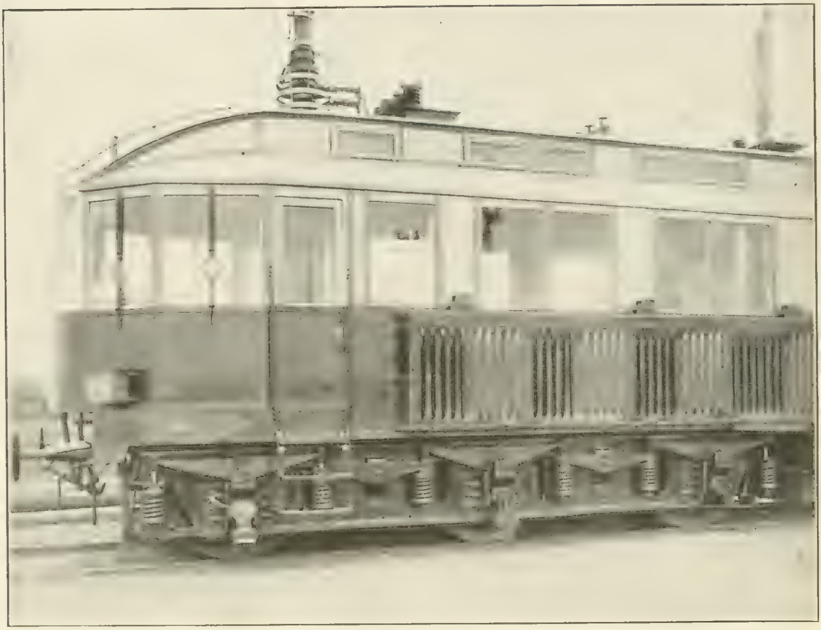


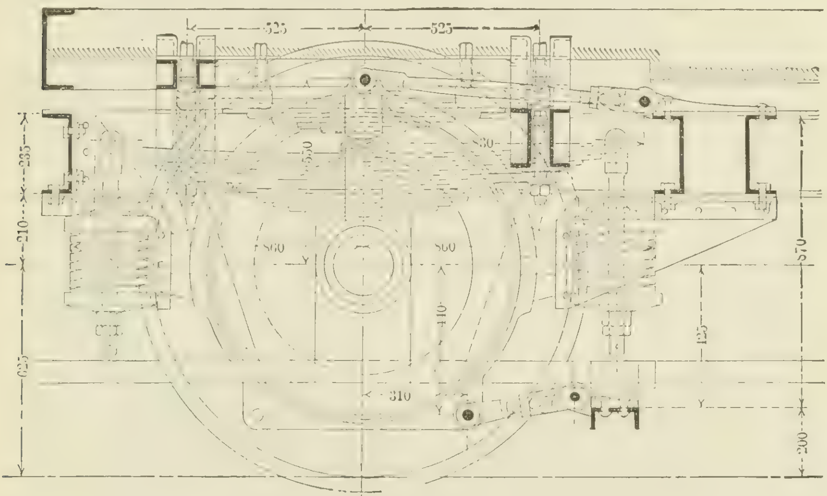
FIG. 1.—THE TRUCK; IDENTICAL ON BOTH CARS.

FIG. 2.—NORMAL RAILWAY CARRIAGE USED IN TRACTION EXPERIMENTS, NOW BEING MADE BY THE UNION ELEKTRIZITÄTS GESELLSCHAFT.

wheel with or without the agency of compressed air. These equipments have given satisfactory results with both carriages and proved very effective, affording full protection against the electric current.

Transformers.—The main characteristics of the transformers used in each of the cars are as follows:

In the transformers of the Siemens & Halske car the effective iron sheets are placed vertically on their small edges and distributed in groups, between which there is space for the passage of air. The secondary coil is well insulated from the iron cores, the coils of the primary winding being placed above it. In the ventilating channel of the iron cores there are protective boxes prolonged as far as the front plates of the casing and expanding into the latter so as to facilitate the drawing in of the air.



Suspension of the motor on the Allgemeine Elektrizitäts-Gesellschaft car.

The transformers in the Allgemeine Elektrizitäts-Gesellschaft car are designed, according to the patents of this company, with three parallel iron cores, the axes of which run longitudinally. Each iron core is provided with a longitudinal slot, through which, as well as between the rectangular cores and the round coil, an air current is allowed to pass. The transformers in both cars have given full satisfaction, the strong air currents proving particularly effective and preventing any considerable heating effects.

The motors.—The motors of the Allgemeine Elektrizitäts-Gesellschaft car are designed for an output of 250 horsepower each, provided with fork-bar coils. The exciting current has a tension of 435 volts. The motor cases are fixed on an iron frame supported on both sides of the carriage by plate springs, each of which is fixed on the main bearing spring of the car. The motor casings each bear a hollow axle,

slipped over the car axle, on which the armature of the motor is built. The motor is coupled to the wheels of the corresponding axle by means of double arms attached on both ends of the hollow axle and touching the sliding pieces placed on the wheels. The weight of the motor, instead of resting immediately on the axles of the car, is thus supported by bearing springs on the axle boxes of the truck.

The motors constructed by the Siemens & Halske Company on the other hand are 6-pole motors, also for outputs of 250 horsepower each, the energy current being conveyed to the rotor at a tension of 1,150 volts by means of three sliding rings. The pressure in the secondary circuit at rest and at first starting is 650 volts. The rotor is provided with closed direct-current bar windings, whereas the stationary part of the motor has rotary-current bar windings. The rotor with its box is pressed strongly on the axle of the car. The stationary part of the motor, inclosed by a double cast-iron casing, rests without any intermediate spring on the car-axle bearings. The diameter of the rotor is 780 millimeters, whereas the external diameter of the motor is 1,050 millimeters.

Both the direct fixing of the motors on the axles and the suspension by springs on the truck have given full satisfaction in connection with the experiments so far made. In general, the spring suspension seems to be preferable to the rigid suspension of the motor.

Exciters and resistances.—The exciters and resistances, necessary in starting and in controlling the speed, show also some essential differences in the two carriages. In order to avoid any abrupt variations in the speed and any excessive sparking in the car, the resistances must be switched off from the circuit quite gradually. In the Allgemeine Elektrizitäts Gesellschaft car there are to this effect liquid resistances of the following construction:

The terminal plates of the opened circuits are placed in two reservoirs in the central machine room of the car. Beside each of the reservoirs there is an electrically driven centrifugal pump, conveying into the upper reservoir a soda solution placed in a box below the carriage. The higher the liquid in the latter the smaller will be the resistance between the electrodes. The height of the liquid is regulated from the driver's cab by means of a valve. The pumps work permanently during the run, the liquid circulating in a tube conduit insuring a permanent cooling (refrigeration). This exciter affords the advantage of dispensing with the contacts and cable joints necessary in connection with solid exciters.

In the Siemens & Halske car, on the other hand, there are metallic resistances, formed of "Kruppine" bands 45 by 2 millimeters in section. These bands are placed by groups in flat boxes fitted outside on the longitudinal wall of the car, below the window. There are in all 29 steps, four being intended for the first inserting and 25 for increasing

THE NIEDERSCHÖNWEIDE-SPINDLERSFELDE TRACK AND DOUBLE AERIAL SUSPENSION USED IN THE UNION ELEKTRIZITÄTS GESELLSCHAFT.

The scene of a series of independent experiments.

and regulating the speed of the motors. Below the resistance boxes there are the exciter rollers placed longitudinally and bearing bronze contact pieces; the corresponding contacts are attached to two steel tubes placed one beside the other and isolated from them. In order to avoid any such disturbances as would attend on an abrupt increase in collecting the current, the single contacts are inserted not simultaneously but successively. The exciting rollers are actuated through a longitudinal spindle traversing the whole of the car, rotated from the driver's stand by means of a conical toothed gearing. In order to facilitate the handling of this controlling device, there is a compressed-air apparatus assisting the driver in starting and reducing automatically the exciter to its zero position if the current has to be switched off. By means of a special gearing the controlling may be effected also without the aid of compressed air.

The trials.—In connection with the trials made in the course of the fall of 1901, speeds as high as 150 kilometers, and even in one case 160 kilometers, were obtained. As, however, rather material oscillations and shocks were experienced even at speeds of 140 kilometers per hour, no further increase of the speed was thought advisable for the moment, the remainder of the year being given up to very valuable measurements and records on the consumption of electric energy. The acceleration obtained after starting was different according to the strain the source of power was put to and the performance of the motors. In order to attain speeds of 100 kilometers, starting distances of 2,000 to 3,200 meters, and starting times ranging between 138 and 220 seconds were necessary, these figures corresponding with a mean acceleration as high as 0.13 to 0.20 meters per second. As, however, the motors are capable of supplying for short intervals about 3,000 horsepower, whereas for the above acceleration only 700 to 1,000 horsepower are required, this represents by no means an upper limit.

As regards the braking of the cars, both cars may be stopped either by means of Westinghouse rapid brakes, hand brakes, or using back current; the Allgemeine Elektrizitäts Gesellschaft car is in addition fitted with an electric brake. The Westinghouse and electric brakes may be operated from each motorman's stand simultaneously, though the braking equipments are independent for either of the trucks. In the case of an air pressure as high as 6 atmospheres in the braking cylinder, two of which are placed on each truck, the pressure on each of the 24 braking shoes arranged on both sides of the wheel is about 6,000 kilograms, the braking shoes thus receiving a total pressure as as high as 144,000 kilograms—156 per cent of the weight of the carriage. * * *

After the trials made in the course of 1901, a thorough rebuilding of the track, as above stated, was found necessary. This occupied part of the year 1902, the remainder of which was taken up in the

continuation of the experiments on the consumption of energy, etc., for speeds up to 130 kilometers. The results of the improvements made last year were shown, in connection with the recent trials, to be most satisfactory and even surprising. The track not only stood easily the strain to which it was put by trials at ever increasing speeds, but the cars would now run with such safety and steadiness as to make the shocks of the rails nearly unnoticeable.

The Siemens car was first given a chance to show its possibilities; after reaching speeds as high as 189 kilometers per hour at the end of September last, it was anticipated that resuming the experiments at the beginning of October would lead to the maximum speed of 200 kilometers being finally reached. This was actually the case on October 6, the event being watched by a great number of lookers-on. The distance between Marienfelde and Zossen was repeatedly traversed in not more than eight minutes each way, including starting and braking, the maximum speed of 201 kilometers (126 miles) being actually reached on the section Mahlow-Dahlwitz-Rangsdorff, traversed in one and one-half minutes, throughout about 5 kilometers. The mean speed of 175 kilometers per hour would enable the journey between Berlin and Cologne (577 kilometers) to be completed in about three and one-fourth hours, whereas the fastest present trains require fully nine hours.

This result, which aroused such sensation in the engineering world, was exceeded on October 23, when 207 kilometers were reached without any disturbing factors being noted.

The Allgemeine Elektrizitäts Gesellschaft car had meanwhile in turn resumed the experiments, both cars being alternately used in the course of October. In order to ascertain first the working conditions of the car, moderate speeds were used at the beginning, which, however, could rapidly be increased, so that the high-speed car of the Allgemeine Elektrizitäts Gesellschaft on October 28 even slightly exceeded the record made by the Siemens car, reaching the enormous speed of 210 kilometers per hour. Both cars ran so steadily that all those present were highly satisfied.

From a car running at such exceedingly high speeds neighboring objects, of course, will disappear from view. Though the motorman would be able to distinguish obstacles on the track, this would be of little use, the braking distance, i. e., the distance from the beginning of braking to the stopping of the train, being 2 kilometers, and 1,600 horsepower having been necessary to obtain the desired speed. Lookers-on could just distinguish the presence of men in the car; before, however, they were able to fix their figure the car had disappeared from view. Though the track is very straight there elapsed at most one-half minute between the first appearing of the train and its passage and thence to the instant of its disappearance on the horizon.

As the maximum authorized speed has now been reached it is not intended, for the moment being, to drive the speeds up to any higher figures, but to complete the measurements already made by an extensive series of records, so as to ascertain fully the working condition of high-speed electric railways. It is thought probable that under existing conditions speeds as high as 230 to 240 kilometers per hour may be obtained without any difficulty, but as no authorization is obtained for the moment this will have to wait for next year. It is thought probable that after the successful results of these trials some railway will be equipped according to the principles ascertained on the military railway so as to allow of these interesting trials being continued on a larger scale.

THE BEGINNINGS OF PHOTOGRAPHY—A CHAPTER IN THE HISTORY OF THE DEVELOPMENT OF PHOTOGRAPHY WITH THE SALTS OF SILVER.[a]

By Maj. Gen. J. Waterhouse, I. A.

Photography proper, i. e., the art of delineating images of external objects by the agency of light upon chemically prepared sensitive surfaces, does not seem to have been seriously thought of, still less practiced, before the end of the eighteenth century. The publication of Wedgwood and Davy's experiments in 1802 showed not only the possibility of reproducing copies of drawings or paintings on glass, by contact, upon a sensitive surface of paper or leather impregnated with silver nitrate, but also gave the first idea of fixing the images of the camera obscura on such a surface. The results obtained by them were, however, very imperfect, and photography did not take any practical shape until the time of Niépce, Daguerre, Reade, and Talbot, between the years 1825 and 1840. But long before Wedgwood's time, and especially during the last two or three decades of the eighteenth century, when the science of chemistry received such rapid development, considerable attention had been given to the chemical and physical action of light in changing the appearance of many metallic compounds and organic substances, notably the blackening of animal or vegetable tissues by silver nitrate, the darkening of the white silver chloride and other metallic salts, and the darkening or bleaching of many organic dyes and resins, etc. On the other hand, Newton's discovery of the compound nature of white light gave an impetus to the study of the physical nature and of the chemical and optical properties of light and color which in more recent years has had and must continue to have a very strong influence on the further development and progress of photography. Again, Kepler's investigations of the optical principles connected with the projection of images of external objects upon a screen by means of lenses, single or combined, and the camera obscura form the basis of modern photographic optics.

About three years ago, when looking up some of the earlier chemical writers for inquiries of my own relative to the action of light upon

[a] Read before the Royal Photographic Society of Great Britain, April 28, 1903, and reprinted, after revision by the author, from The Photographic Journal, London, Vol. XLIII, June, 1903.

silver and its compounds, I commenced collecting material for an investigation into the evolution of photography with the salts of silver. My attention was, however, diverted to the optical side of the question connected with the history of the camera obscura and the telephoto lens, and the results of those inquiries have been published in the Journal.

The publication of the late Mr. R. B. Litchfield's biography of Tom Wedgwood, the first photographer, which was intended as a centenary memoir of the founder of the art, has renewed my interest in the subject, and the further investigations I have lately made have, I think, thrown quite a new light upon the early history of photography and shown how it was gradually developed from Schulze's rough experiment with silver nitrate and chalk, and finally brought about, though imperfectly, by Wedgwood and Davy. This retrospect seems the more opportune now that a century has passed since Wedgwood's work was first made known, and we are about to celebrate the jubilee of our society which, however, was not founded until after the invention of collodion had put photography on a thoroughly practical basis.

The main facts in the early history of the progress of photo-chemistry and optics tending to photography have been noted in Prof. J. M. Eder's admirable Ausführliches Handbuch der Photographie (Part I, 1891), in which I have found many useful references to the early writers and literature. I know of no English work in which the subject has been treated with the fullness it deserves. And this is the more to be regretted because so much of the early investigation was done by Englishmen and is almost unknown. Robert Hunt's Researches on Light has no pretensions to be a history, while W. J. Harrison's History of Photography, though it contains a short summary of the early work, is more devoted to the record of progress in practical photography since 1839. The story of these early experiments is, however, an interesting one; and although I can only give a brief and necessarily very incomplete sketch of it, this may serve to draw attention to the subject and incite further inquiry.

EARLY NOTICES OF SALTS OF SILVER.

Nitrate of silver seems to have been known from very early times. Doctor Vogel infers from Herapath's statement that silver has been found on linen mummy cloths marked with hieroglyphs that the ancient Egyptians knew of the darkening action of light upon silver nitrate. (W. and T. J. Herapath, Phil. Mag. (iv) 3, 528, and 5, 339.) One of the earliest authentic accounts of it is given by Jabir ibn Hayyam (commonly known as Geber), who lived about the seventh or eighth century. In the quaint English translations of his works by Richard Russel (1678) we find a clear description of nitric acid (dis-

solutive water) prepared by distillation of a mixture of vitriol of Cyprus (copperas), saltpeter, and alum. By adding sal ammoniac a kind of aqua regia was formed, which he says would dissolve gold, sulphur, and silver. By dissolving calcined silver in its solutive water (nitric acid), and allowing a third part to evaporate, he obtained the nitrate in the form of small fusible stones, like crystal. (Invention of Verity, cap. 2, p. 266.) He also mentions a peculiar celestine or hyacinth color produced by exposing silver to the fumes of acute things—as of vinegar, sal ammoniac, etc. Later on we find a great many references to this silver blue pigment in the writings of the early chemists and painters. In some cases the color was no doubt due to the verdigris formed by the action of strong vinegar on the copper alloy mixed with the silver, but in others it may have been a form of chloride or compound chloride of silver with ammonia and copper of an intense blue color. So that silver chloride may have taken its place in pictorial art very much earlier than is generally supposed. Entzelius, in his De Re Metallica (Frankfort, 1557, p. 17), mentions a plum-colored silver ore which, according to Theophrastus, was used as a fine pigment. He also notes the great variety of color shown by the ores of silver.

We may pass over Albertus Magnus and the alchemists of the eleventh to the fifteenth centuries, whose methods of making nitric acid, silver nitrate, and aqua regia were for the most part derived from Geber. And though they must have been acquainted with silver chloride, they have, so far as I have been able to ascertain, left no record of the action of light upon it or any other silver compound. Little, indeed, to this effect can be found in the works of the earlier mineralogists and metallurgists of the sixteenth century, who mention several different ores of native silver, but seldom under the name of horn silver, or luna cornea, and it is very difficult to ascertain which of the many translucent ores described by them really was the native chloride.

One of the earliest and by far the most important of these writers, Georgius Agricola (Georg Bauer), in his De Natura Fossilium, liber 8, written about 1546, mentions silver as producing black lines and dirtying the hands; acids also corrode it, tinge it blue, and destroy it. In another passage, in liber 10 of the same work, he describes an excellent method of making the blue pigment above referred to by exposing sheets of silver full of small fissures, which should be filled up with mercury, to the vapors of a mixture of sal ammoniac dissolved in the strongest vinegar in a closed vessel buried in the earth or in dung for about twenty days.

The best edition of his De Re Metallica and other works, published at Basel in 1657, is a complete treatise on mining and metallurgy, illustrated with many curious pictures of mines and mining machinery.

In an index at page 702 of this book we find the German equivalents to the Latin names of a number of ores of silver, but there is no mention whatever of horn silver, nor have I found any distinct reference to it in the volume. Nor is there any reference to the darkening of these ores by light, though he says of one form of Tyrolean glassy ore (argentum rude rhêticum, probably a sulphide) that from a blue inclining to violet it blackens or is ash colored.

FABRICIUS AND OTHERS ON HORN SILVER.

In a note to a memoir on Daguerreotype, written about 1839, Arago says (Œuvres complètes, 7, 466) that in a work by Fabricius (De Rebus Metallicis, 1556) there is a full description of a kind of silver ore called "horned silver," with the color and transparence of horn, the fusibility and softness of wax. Exposed to light, it passed from a yellowish gray to violet, and by a more prolonged action became almost black; it was natural horn silver. Tissandier (History and Handbook of Photography) makes Fabricius an alchemist and says that he prepared luna cornea by precipitating a solution of silver nitrate with sea salt, and that in his Book of the Metals (1556) he relates that the image projected by a glass lens onto a surface of luna cornea imprinted itself in black and gray according as the parts were completely illuminated or touched only by diffused light. Harrison, in his History, also gives a similar account.

Becquerel, Eder, and Fabre have already noted that there is nothing to this effect in the little treatise De Metallicis Rebus ac Nominibus, observationes variæ et eruditæ, ex Schedis Georgii Fabricii: quibus ea potissimum explicantur, quæ Georgius Agricola præteriit, compiled from notes by Georgius Fabricius (Georg Goldschmied) sent by his brother to Kentmann and published in 1566 by Conrad Gesner, of Zurich, in a collection of similar treatises on gems, fossils, minerals, etc. In the chapter on silver (p. 6) Fabricius says: "In no metal is there such a great variety of colors as appears in this by some marvelous artifice of nature: some ores are translucent, as the red or liver-colored, another is like a ruby, a third has a horny light (lucem corneam) and is very like cornelian (sarda)." Again he says that "the liver-colored ore is described in his book of metals (in nostra corpore metallico). This also is soft like lead and melts over a candle; poured out on gypsum, on account of its spiritual subtility it is entirely consumed. Its thinner particles are translucid like horn, the thinnest like ice." In a list of various ores of silver (p. 10) he mentions one (cornei coloris translucidum), translucid with the color of horn, but that is all; not a word about any change of color by exposure to light or otherwise. From the above it seems possible that Fabricius wrote an earlier work on metals, but I have not been able to find any trace of it. From 1553 till his death, in 1571, he was director of the college

at Meissen, and was the author of several philological, historical, and poetical works (P. Albinus, Meissniche Land-Chronica, p. 322). His treatise on metals, referred to, is not in the least alchemistic. Son of a goldsmith, born and living in the mining districts in Saxony, it is natural that he should have taken an interest in metals. So far as I have been able to gather, the accounts of his observations of the action of light on horn silver, or silver chloride, are quite apocryphal.

In G. D. Schreber's Life of Fabricius (1717) we find several passages showing the friendship that existed between Fabricius and Agricola and the help given to the latter by the former in compiling his book, to which the notes by Fabricius were intended as a supplement and were so published in the edition of 1565.

In another treatise in the same volume, by Johann Kentmann, describing the minerals of Misnia (Meissen) there is a list of 84 different ores of silver, and among the yellow ones he describes one as "pellucid like horn, from Marienberg: melts over a candle."

The only distinct early notice of horn silver and of its change of color I have come across is in a little German book by H. Modestin Fachs, mint master at Leipzig, Probier Buchlein (1567). At page 184, in a list of silver ores, he mentions horn silver ore (Horen Silberertz) and says: "It looks just like horn, such as is used for horse combs, and may be cut and impressed like wax; is very rich in silver. Like it, such horn silver is wont also to change to the color of oxidized lead (bley nichter.)"

Johann Mathesius, in his Bergpostilla, or Sarepta (1578), mentions horn-colored silver ore as lately found in the Marienberg mines, transparent like the horn of a lantern and fusible over a flame. (This may explain why Agricola does not notice it.) He does not note the change of color on exposure, but in the Meissnische Berg-Chronica (1590), page 110, Petrus Albinus describes a remarkable white semifluid silver ore from St. Georgen, which was said to be like buttermilk when found, but soon hardened in the air, becoming like sand or grit, and its white color changed to brown or rusty. This semifluid ore is also noticed by Albertus Magnus and Agricola, but there is nothing to show it was a chloride. Albinus also mentions horn silver from Marienberg (p. 127) in much the same terms as Mathesius, and, with regard to the variety of colors it assumes, he quotes the extracts from Fabricius, given above, as referring to this ore. In this way the early knowledge of native horn silver and its liability to change of color seems to have been entirely confined to the mining districts of Saxony.

Even in the great work of Aldrovandus, Musæum Metallicum (1648), although we find a very full and interesting account of silver and its ores, with many illustrations, nothing definite is said about horn silver. Nor does Father Kircher mention it in his Mundus Subterraneus (1665).

From the sixteenth century onward the science of chemistry as distinct from alchemy, or the search for the philosopher's stone and transmutation of metals, began to develop in connection with medicine under the impulse of the teaching of Paracelsus and his followers. Tinctures of gold and silver being considered of high remedial value, attention was paid to the preparation of salts of these metals. It is in a book of this kind, the Basilica Chymica, by Oswald Croll (Frankfort, 1608), we have perhaps the first distinct mention of the precipitation of silver chloride by adding salt water to a solution of silver in aqua fortis. He mentions its fusibility, softness, and capability of being cut by a knife, and calls it, from its horn-like appearance after fusion, "that unknown luna cornea," and warns his readers against it being used in combination with lead to prove the transmutation of metals, the falsified lead being apparently turned into silver. He says nothing, however, about any darkening in light.

In the translation of Erckern's book on Assaying, by Sir John Pettus (Fleta Minor, 1683), page 5, he refers to the horny ore of silver as being called so from its transparency, or rather lucidation, like horn, and very rich in silver next to certain glass ores, or sulphides. In the same way, C. K. Schindler, in Der Geheimbde Münz Guardein und Berg Probierer (1705), mentions horn ore as a kind of transparent ore like the horn of a lantern and of rich yield.

That these horny ores of silver were identical with the luna cornea or horn silver, formed by fusing the precipitated chloride, seems doubtful from the account of them given by J. A. Cramer in his Elementa Artis Docimasticæ (1739), of which there is an English translation by Dr. Cromwell Mortimer (1764). Horny silver ore is described as semitransparent, of a deeper or lighter yellow or brown color, according to the size of the pieces, looking like resin, easily powdered, and lamellar in structure. When strongly heated it emits sulphurous and arsenical fumes and only contains two-thirds of silver.

In the second part of the book he describes the purification of silver by precipitation as chloride with muriatic acid from the solution of the nitrate. If the precipitate is dried and melted and poured out quickly "it appears as a body of a light scarlet color, half transparent, ponderous enough, and so tenacious that it is difficult to reduce it to powder, and if you break it, it seems to be of a fibrous texture within; whence it is called 'Lunæ cornua,' on account of its resembling the horns of animals on the outside." He, however, says nothing about this substance being darkened by exposure to light, nor of its relation to the horny silver ore.

CRONSTEDT AND WOULFE.

We find the first distinct recognition of the identity of the true hornertz, or horny silver ore, with the luna cornea, or horn silver, prepared by precipitation from the nitrate in Cronstedt's essay toward a

system of mineralogy (1758), of which an English translation by von Engestrom and Costa appeared in 1770, and a second edition by Magellan in 1788. He says that the horn silver ore is the scarcest silver ore; it is of a white or pearl color, changeable on the surface, semitransparent, and somewhat ductile when crude and when melted. It can not be decomposed without some admixture of such substances as attract the combined acid of the sea salt. Although he notes the blackening of the glassy ore or sulphide in the air, he does not clearly mention the blackening of the horn silver. In Magellan's edition the darkening of this ore to a violaceous brown when exposed to the sun's beams, as happens also to the artificial horn silver, is mentioned in a note.

The first definite chemical analysis of crude mineral horn silver compared with the artificially prepared, was made by Peter Woulfe (Phil. Trans., 66, 1776, 608). He notes the confusion existing between the horny ores and the glassy ores, containing sulphur and arsenic, and says that Cronstedt and Le Sage asserted that the native horn silver was composed of silver and sea salt only. Woulfe also found some sulphate, amounting to about one-third of the chloride, and in some samples admixture of sulphides. He says nothing about the darkening in light, but mentions a black horn silver.

DARKENING ACTION OF SILVER NITRATE.

On the other hand, the darkening action of silver nitrate was known much earlier. It is generally said that Albertus Magnus was the first to record it in his Compositum de Compositis, but this is not correct. After his description of the preparation of nitric acid, which is very similar to Geber's, he says: "It dissolves silver and separates it from gold; it calcines mercury and crocus martius; it stains the human skin with a black color difficult to remove." As given in the texts this latter passage certainly refers to the acid and not to the solution of silver. But there may have been some silver in the acid.

In J. B. Porta's Magia Naturalis (1589) liber 10, caption 20, we find a modification of Geber's old recipe for making aqua fortis, for parting silver from gold, by distilling niter and alum, also for making aqua regia by adding sal ammoniac to the other ingredients, and another for sulphuric acid. In liber 16 he gives a number of methods for secret writing, among others writing on the skin with a solution of silver in aqua fortis, and in liber 20 he gives a method of disguising oneself for some time by applying the same solution over the body. It is curious that he should not have thought of applying the solution to paper.

In the well-known work by Caneparius, De Atramentis (1619), dealing with the preparation of pigments and inks of various kinds, we might have expected to find mention of the use of a solution of nitrate

of silver as a sympathetic ink or as an indellible marking ink, but he says nothing of this, though he mentions the use of silver for writing.

He gives, however, several recipes for making azure blue pigments from silver, gold, and mercury, which, in the case of silver, all depend on the formation of an impure chloride, or double chloride of silver and copper, by the action of the vapors of vinegar and sal ammoniac upon thin plates of silver inclosed in a tight vessel and left for some time under warm dung or grape husks, etc. There is no mention of any addition of mercury as recommended by Agricola.

Angelus Sala, in his Opera Medico-Chymica (1647), mentions the staining of the hands by solution of silver nitrate, but says it has not the strong corrosive action of nitric acid, and when some of the salt was kept in paper for about a year the paper was darkened but not corroded. He also notes that powdered lunar caustic (lapis lunaris) exposed to sunshine appeared like the blackest ink; this was afterwards quoted by Kircher. He noticed the same change of color if it was mixed with solution of gold. He gives full instructions for crystallizing the solution of lapis lunaris. Sala was the first to recognize ammonia as a separate body.

In Glauber's Opera Chymica (1658) there are several passages relating to the use of nitrate of silver solution for staining hard woods like ebony, or for dyeing leather or feathers black, and this is perhaps the first mention of the practical use of it for such purposes. In Christopher Packe's excellent translation of Glauber's works (1689), Philosophical Furnaces, Part II, caption 28, page 26, a method of preparing crystallized silver nitrate is described, and the solubility of the chloride in ammonia is noted as follows:

> The remaining solution which is not crystallized, you may, in a copper vessel by adding sweet water thereto, precipitate over the fire into a calx and then edulcorate it and dry it and keep it for other use. Or else you may precipitate the same with salt water and so edulcorate and dry it; and you will have a calx which doth melt by a gentle fire and is of a special nature, and in the spirit of urin, of salammoniak, of hartshorn, of amber, of soot, and of hair it doth easily dissolve, and it may be prepared or turned into good medicines as shortly in our treating of the spirit of urin shall be taught.

After describing several medicinal preparations of silver, as well as a green oil, made with spirit of sal ammoniac and useful for silvering metals or glass he goes on to mention other uses of silver crystals:

> Lastly, there be many pretty things more effected (besides the medicinal use) by means of crystal of silver—viz, when you dissolve them in ordinary sweet rainwater you may dye beard, hair, skin, and nails of men or beasts into carnation or pink red, brown, or black, according as you have put more or less thereof in the water, or else according as the hair was more or less wetted therewith, whereby the aspect of man or beast (which sometimes in several occasions may not be contemned) is changed so that they can not be known.

He says very little about the chloride, and had apparently no idea of the action of light or sunshine in producing the change of color in organic matter by the action of silver nitrate.

In the same way Robert Boyle frequently mentions the staining of the skin by solutions of silver or of gold and also the darkening of the chloride in the air, but seems to have had no idea that it was due to the action of light. Thus, in his General History of the Air (1692), page 53, he says:

> If we precipitate a strong solution of good silver made in aqua fortis with a competent quantity of spirit of sea salt we shall have a pouder which at first will be very white; but if the liquor be not poured off, this being exposed for a good while to the air, it would acquire on the surface a dark colour, which perhaps an attentive eye will discern somewhat various, as this or that kind of saltness happens to be predominant in the air.

At page 52 he mentions that silver plate exposed to the air in Amsterdam is very readily tarnished, and it is evident that he looked upon the darkening of the chloride as something analogous and due to saltness or impurity in the air.

Nicolas Lemery also describes the preparation of a medicinal "lunar tincture" made by dissolving precipitated silver chloride in spirit of urine and spirit of wine. He says, further, that the precipitate of silver with salt darkens on drying, even in the shade, no doubt on account of a small quantity of copper present.

SCHULZE'S OBSERVATIONS.

Although the writings of Kunckel and Stahl contain a good deal about the chemistry of the compounds of silver and their reduction by heat and chemical methods, we find no observations of the darkening by light, and the first investigation of this action was made by Johann Heinrich Schulze, who published an account of his experiments in the Acta of the Cesarean Academy for 1727. (A full translation of this paper appeared in this journal for 1898, p. 53.) Though these experiments were mentioned by Priestley and other authors, and, as I propose to show, in all probability led the way to Wedgwood's work, they seemed to have entirely dropped out of sight until they were brought forward by Doctor Eder in 1881, in his history of photography published in the Photo. Correspondenz. Like many valuable discoveries, they originated with the investigation of an accident. Schulze tells us that while experimenting on the preparation of the Bolognian phosphorus, with a mixture of chalk saturated with some aqua fortis which contained a small quantity of silver, at an open window, he was surprised to find the color of the surface changed to a dark purplish red, while the part untouched by the sun's rays remained unchanged. This curious fact struck him so forcibly that he put aside his original experiments to investigate the cause of the darkening. His friends

suggested that it was due to heat, but experiment showed it was not so. He then divided the mixture into two parts, one being kept in the dark while the bottle containing the other was put in the hot sun with a thread passed round it about the middle of the part exposed to the sun. After some hours' exposure the thread was removed, and he was delighted to find that under it the color of the mixture was the same as that in the back part of the bottle, which had not been exposed. The experiment was repeated in various ways, and proved that the change of color depended entirely on the sun's light, and that heat had nothing to do with it. He then tried experiments in the converse way, i. e., he mixed up the fluid to give it a uniform color, and then covered the greater part of the glass with opaque bodies, or with cut-out words or sentences on paper, leaving only a small portion of the mixture exposed. In this way the words or sentences were accurately and distinctly reproduced on the chalk sediment, and the result was looked upon as a great marvel by ignorant people.

Feeling that still further investigation was necessary, and believing that the effects were dependent on the mixture of chalk and aqua fortis, he tried several experiments with fuming spirits of niter and ordinary aqua fortis mixed with chalk, but obtaining no result, he remembered that the aqua fortis he had first used contained some silver, and that the effects must have been due to it, because he had already noticed that solutions of silver in aqua fortis turned dark red after exposure to the sun. He then repeated his first experiments with an aqua fortis containing more silver, and observed that the color was more distinctly marked than before. He found also that reflected sunlight was capable of producing the same result. He notes that other white substances, such as hartshorn, white magnesia, ceruse of lead, can be used to show the same effect as with the chalk. Even then he seems to have felt that he had not penetrated to the real cause of the phenomenon, and only suggests the use of it as a means of testing the presence of silver in a solution. He evidently had no idea of its photographic possibilities.

Although Schulze did not set out with the idea of making photographic copies by means of his silver and chalk mixture, and his cut-out stencils were only used to give a clear demonstration of the action of light, it must be acknowledged that his experiments were distinctly photographic in that he first produces his negative images of the thread, leaving a white line on a dark ground, and then the positive images, dark on a white ground, of his cut-out words and sentences, or in modern parlance his negative, or cliché. There is no doubt that here we have the germ of the photographic idea, and further on I shall endeavor to show how it was taken up in this country and led more or less directly to Wedgwood's own experiments.

DU FAY AND HELLOT.

In the Memoirs of the French Academy for 1728, page 50, Du Fay has described a method of staining agates by treating them with a solution of silver nitrate, and when dry exposing them to sunshine; the solution, penetrating to different depths in the more or less absorbent layers of the stone, produced variegated effects not shown in the original. In some cases the solution was applied with a pen. Du Fay seems, however, to have had no idea of using a stencil, and to have worked, though almost contemporaneously, quite independently of anything done by Schulze, the staining of objects by silver nitrate solutions being, as we have already seen, well known, though the necessity of the objects being exposed to light was not so clearly recognized. He also used solutions of gold and bismuth, and notes the favorable effect of a certain amount of moisture in strengthening the reduction.

Similarly, Hellot, in the same memoirs for 1737, mentions the use of a weak solution of silver nitrate as a sympathetic ink which would show nothing so long as the paper were kept in darkness, but on exposure to the sun darkened and showed the writing in a slaty gray, this effect being due, as Hellot thought, to the action of some sulphurous principle in the nitric acid which blackened the silver. This is interesting as, apparently, the first recorded graphic application of silver nitrate to paper.

BECCARI'S OBSERVATIONS.

We have already pointed out the incorrectness of the commonly accepted statement that Georgius Fabricius was the first to publish the fact that luna cornea, or silver chloride, darkened on exposure to light, and, although this darkening must have been constantly observed, it was, even up to Boyle's time, not attributed to the action of light, but rather to some effect of the air or sulphurous vapors. That it was due to the action of light was first proved by Jacopo Bartolomeo Beccari, of Bologna, in 1757, by a method very similar to Schulze's with the nitrate. His paper, in the fourth volume of the Commentaries of the Bolognian Academy, deals with the power which light possesses of itself to change not only the colors but likewise the texture of things.

Having a suspicion that the change in color of luna cornea, generally attributed to the action of the air, was due to light, he inclosed some in a glass vessel and placed it at some distance in front of the window of a room not very brilliantly lighted. After some time he noticed that the luna cornea on the side toward the window had turned violet, while that on the other side away from the light retained its original color. This showed that there was some influence in light which caused changes of color. To make quite sure, however, he fixed

some black paper on the unchanged side of the vessel to see if it would protect the silver salt, and left it again exposed till next day, when, on returning to it, he found that the luna cornea had turned violet everywhere except in the parts protected by the paper. From this he concluded that the change was due more to the action of the light than of the air, and that the same is probably the case with the fading of the colors of garments, for fullers when dyeing the more costly cloths only consider a dye good if the color remains unchanged after a long exposure in full daylight, though they probably attribute the injury to the effect of the air rather than of light. The remainder of the paper is devoted to experiments by Bonzo on the changes of color of silken ribbons in light. Here, as in the case of Schulze, Beccari's experiment was more photochemical than photographic.

DR. WILLIAM LEWIS'S INVESTIGATIONS.

So far it had been recognized that the change of color of silver compounds was due to the action of light, but nothing had been done to show what chemical changes took place during this action or what were the conditions to be fulfilled, and the first to make any investigation in this direction was Dr. William Lewis, M. D., F. R. S., the author of many works on technical chemistry. In his Commercium Philosophicum Technicum, or Philosophical Commerce of Arts (1763), he has given a very full account of his investigations into the cause of the coloration of ivory, bone, wood, or stone treated with solution of silver nitrate and exposed to sunshine. He repeated Schulze's experiments with chalk moistened with solution of silver nitrate, both while wet and after being dried, and notes that the color is produced only on those parts on which the sun shines, and that distinct characters may be exhibited on the mass by intercepting a part of the sun's light by threads or cut paper. He found that the color thus produced on the chalky mixture was not so deep as it was on bone or ivory and was entirely superficial, so that by shaking up the mixture it again appeared white. By exposing the mixture constantly to light for many weeks and frequently shaking it, he was able to darken it throughout, though weakly. The light of a candle or the ordinary warmth of a fire had no effect, but at a considerable heat the matter became brown, though it did not become black as it did in the sun.

He also tried several earthy bodies and found that those which dissolve in acids, the ashes of vegetables, of bones and horns, darkened in the same way as chalk and other mineral calcareous earths. Powdered flint remained perfectly uncolored, even after six months' exposure in the sun. White clay, plaster of Paris, and powdered talc also remained uncolored; and even chalk itself, previously satiated with vitriolic acid so as not to be acted upon by the acid in which the silver was dissolved, was unchanged. He concluded, therefore, that to pro-

duce a black stain from solution of silver, it was necessary not only that the substance moistened with it should be exposed to the action of solar light, but that it should contain some matter which the nitrous acid might dissolve preferably to the silver which it already held dissolved. He observes that though this is plainly the case with bones, horns, hair, marble, and other bodies which are stained by the silver solution, there are also some stones, such as agate, in which a substance soluble by the acid has not yet discovered itself. (In another place he refers to Du Fay's experiments with agates already noted.)

He goes on to say that this production of a dark color by the action of the sun is not peculiar to solution of silver, or to a combination of this solution with soluble earths, and notes that precipitated nitrate of bismuth and mercurius dulcis, a combination of quicksilver with the marine acid (calomel), suffer a like change, but do not become black like silver. He does not mention the action of light on silver chloride.

In the early part of the book he notes also that the solution of gold in aqua regia stains the skin and other animal and vegetable substances purple, the coloring being hastened by exposure to the sun and free air and favored by the presence of moisture. He mentions several other preparations of the muriate of gold combined with sea salt, niter, or sal ammoniac, as well as solutions in ether and volatile oils. He also discusses the staining power of a solution of platinum in aqua regia in the light and finds it much less than that of gold. It gives a brown stain to organic materials dipped in it, but in most cases water washes off the stain.

CONNECTION BETWEEN SCHULZE AND WEDGWOOD.

These very interesting researches are, like the previous ones of Schulze and Beccari, more photochemical than photographic, though they form a noteworthy contribution to the history of silver printing which has hitherto been quite overlooked. They are the more important because it appears extremely probable that they form the connecting link between Schulze and Wedgwood, for we find in Dr. Thomas Thomson's History of Chemistry (Vol. I, p. 266), that at Doctor Lewis's death, in 1781, all the manuscript volumes containing his experiments and collections from other authors which had been compiled by his assistant, Mr. Chicholm, who had been with him for many years, were purchased by Mr. Wedgwood, who also took Mr. Chicholm into his own service and put him in charge of his laboratory. According to Miss Meteyard (Life of Josiah Wedgwood, 2, p. 465), the name of this assistant was Alexander Chisholm; he had been thirty years with Doctor Lewis, of Kingston-on-Thames, and entered Wedgwood's service at Etruria as secretary and chemical assistant in 1782, and was for a long time his right-hand man. He died in 1807. From Mr. Litchfield's "Tom Wedgwood" (p. 5), it appears that Chisholm (or

Chisolm, as Litchfield spells it) had a great deal to do with the education of young Tom. He was a good chemist, a man of education, and at least something of a classical scholar, and the boy seems to have received much of his scientific and classical training from him, and when at the university corresponded freely with him, chiefly on chemical topics. He no doubt also assisted him in his early experiments. This connection of Chisholm, first with Doctor Lewis and the photochemical experiments recorded in the Commercium Philosophicum Technicum, and then with the Wedgwoods, throws a good deal of light upon the probable origin of Tom Wedgwood's photographic experiments, and it is possible that if any of the correspondence between Tom Wedgwood and Chisholm, or any of the latter's manuscript notes, are still available, some valuable information on the subject may yet be obtainable.

DOCTOR PRIESTLEY.

In 1772 Dr. Joseph Priestley published his valuable History of Discoveries relating to Light, Vision, and Color, and it is interesting to note (p. 378) that he was a believer in the theory that light was a real substance, consisting of particles of matter emitted by luminous bodies, and considered that this view was favored by experiments demonstrating that the color and inward texture of some bodies are changed by exposure to light. He notes Duhamel's researches on the purple color extracted from a shellfish found in Provence, which is developed by sunshine; also Beccari's experiments with luna cornea, already mentioned. With regard to this he remarks that it does not appear that Beccarius knew on what ingredient in the composition the change of color depended, and then he fully describes Schulze's experiments, which prove it to have been the silver. Although Doctor Lewis's book is mentioned in the list of authorities consulted by Priestley in the preparation of his history, he makes no mention of his chemical investigation of Schulze's experiment, but goes on to discuss the further experiments of Bonzius and Beccarius on the action of light on ribbons, etc.; but these do not concern us at present.

In connection with Priestley it may be noted that Josiah Wedgwood, the father of Tom, was a subscriber to this book of Priestley's, and we may agree with Miss Meteyard that it was not unlikely that young Wedgwood would know the book, especially as he was interested in questions bearing on light and heat. Moreover, Mr. Litchfield mentions (op. cit., p. 19) that while working at the long series of experiments described in his two papers of 1791–92 Tom Wedgwood was corresponding with Priestley, who was an intimate friend of the family, and if he were working at photography at the same time it is not improbable that his attention would have been drawn to Schulze's experiment, even if Chisholm had not already told him of it.

We next find Schulze's experiment included by Dr. William Hooper in his Rational Recreations (1774, 4, 143) under the heading "Writing on glass by the rays of the sun." It was repeated by Halle in 1784 in his Magie, oder die Zauberkräfte der Natur, who mentions writing with sympathetic inks made of solutions of gold or silver, and it appears also in later collections of chemical experiments. Here we have the first distinctly graphic application of Schulze's experiment, and nothing else of the kind is given by Hooper. For the purpose of this experiment the cut-out stencils (or, as Schiendl calls them, "negatives") were more suitable than the positive prints or projections used by Wedgwood and Davy. No thought of fixing or of multiplying copies of his light images seems to have occurred to Schulze or to any of those who described his experiment, and, indeed, from the nature of it, it was not likely to do so. In this sense he certainly fell short of the photographic ideal which Davy and Wedgwood undoubtedly had before them.

SCHEELE'S OBSERVATIONS.

In 1777 Carl Wilhelm Scheele published his well-known observations and experiments on air and fire (Aeris atque Ignis examen chemicum. Upsala and Lips. 1777), of which translations were published in German, French, and English. He also was a believer in the prevailing theory of light being a body, and that the light of the sun was the same as of a burning candle. He sets himself to prove the presence of an inflammable principle in light (sec. 60), and starts with the blackening of a solution of silver nitrate exposed to the sun on a piece of chalk, noting that reflected white light produces the same effect, but heat does not; then he asks whether this black color should be real silver, and in the following sections describes a series of experiments he made to prove it. The most important, photographically, are in section 63, in which he describes how he first of all prepared silver chloride by precipitation with sal ammoniac from solution of the nitrate, washed and dried the precipitate, and exposed it on paper to the sun for two weeks, when the surface of the white powder grew black. The powder was then stirred and the operation repeated several times. He then poured some caustic spirit of sal ammoniac upon the darkened chloride, and found that the ammonia dissolved a quantity of the chloride, though some black powder remained. This was washed and dissolved in pure nitrous acid and was again precipitated as luna cornea. Consequently the blackness which the luna cornea acquires from the sun's light, and likewise the solution of silver poured on chalk, is silver by reduction. In further experiments he showed that during the exposure of luna cornea to light under water the latter takes up muriatic acid, which can be proved by its again precipitating luna cornea in a solution of silver nitrate; also that

luna cornea, when exposed to light, moistened with nitric acid, does not change color. In section 66 he demonstrates the presence of phlogiston in light, and shows that light itself is not phlogiston by placing in the colored rays of the solar spectrum paper on which some luna cornea had been spread, when it was found that the darkening took place much more rapidly in the violet rays than in the others; i. e., the calx of silver more quickly separates the phlogiston from the violet than from the other rays. He thus shows that light can not be considered as a simple substance or an element. These observations of Scheele's, scanty as they are, mark a very distinct advance in photochemical knowledge, and demonstrate fully the decompositions that take place by the exposure of silver compounds to light, so far as the imperfect chemical theories of the time allowed. It may be noted that Scheele did not discover the solubility of silver chloride in ammonia, as it apparently was known to some of the alchemists, and, as we have seen, is distinctly mentioned by Glauber and Lemery; also, in 1761, by Marggraf, who describes the preparation of ammonia (spiritum urinosum), and says that he can only say of it that it dissolves luna cornea in the cold. (Chymischer Schriften, pp. 62 and 284.)

SENEBIER AND PHOTOMETRY.

Scheele's observations were repeated and developed further by Jean Senebier, but more particularly with reference to the influence of light on vegetation. His book, Mémoires Physico-chymiques sur l'influence de la lumière solaire pour modifier les êtres des trois règnes de la Nature, et surtout ceux du règne végétal (1782), contains a vast number of interesting observations on the disengagement of air or gas from leaves under water in sunshine, on the production and development of confervæ in water, on etiolation and the effects of colored lights and of the different colored rays of the spectrum on the growth of plants. He recognized the greater activity of the violet ray. He preceded Herschel in the examination of the temperature of the different rays of the spectrum but failed to note the special heating power of the ultra-red rays or the extension of action beyond the violet. In the latter case he placed the chloride in saucers and threw the spectrum on them. Had he used strips of paper he would probably have observed the ultra-violet rays. In many of his experiments he used cut-out masks or shades of metal or other material to cut off the light of the sun from fruit or plants under observation. He, like others of his time, believed that light was a material substance, and also in the existence of phlogiston, so that it is sometimes difficult to translate his meaning into conformity with modern ideas.

He investigated the changes of color in various woods by the action of light, using slips of sheet lead as shades, also glazed boxes fitted with various colored glasses or different thicknesses of the same glass.

He also used colored ribbons or papers in different thicknesses to graduate the amount and color of the light falling on the woods, and thus appears to have been the first to use a photometer. He found that the change of color was due to the resinous constituents of the wood and the liability to change depended on the amount of resin present. He does not seem to have made any observations on changes in the solubility of resins after exposure to light, but apparently recognized that the light brought about an oxidation, and that some resins are bleached while others are darkened.

In the fourteenth memoir (Vol. III, p. 184) he discusses the action of light on mineral substances and, after briefly noting its action on several metallic compounds, he deals, in section 3, page 192, with the compounds of silver, and especially the chloride (luna cornea). He refers to the previous work of Beccari, Meyer, Schulze, and Scheele, and proposes to extend it. Not content with the simple experiment with a cut-out stencil of sheet brass, he instituted a series of photometric observations, by exposing the chloride under a varying number of thicknesses of paper or slips of different woods or of glass. He confirmed Scheele's experiment with the spectrum and extended it by measuring the length of time it took each ray to darken the chloride, and found that while the more refrangible rays at the blue end only took from fifteen to thirty-five seconds the less refrangible from the yellow to the red required from five and one-half to twenty minutes.

Valuable and interesting as Senebier's observations are as a contribution to the science of vegetable physiology, they did not advance photography very much, except in so far as they marked the introduction of a system of photometric measurement, which in recent years has been recognized as the only reliable basis of scientific photographic investigation, and perhaps no one has contributed more to this than our esteemed president, Sir William Abney.

BERTHOLLET.

In the Memoirs of the French Academy for 1785 Berthollet published some researches on the action of light upon plants, etc., as well as upon silver chloride under water, and attributed the darkening of the silver salt to a partial reduction of the metal caused by the disengagement of oxygen loosely combined with it. He explains this as being conformable to a law of affinity under which the adherence of any element increases in proportion as its quantity grows less, and remarks that gold, silver, and mercury are precipitated on animal substances in this medium state between the oxide and the metal. Doctor Eder notes that Berthollet was thus the first to suggest the formation of a subchloride or oxysubchloride by the action of light on silver chloride. Berthollet's views were afterwards changed more

in conformity with Scheele's observation that hydrochloric acid was found in the water after exposure of the chloride to light. (Essai de Statique Chimique, 1803.) He also found that the blackened chloride dissolved in ammonia as well as the white and was unchanged. There was, therefore, no disengagement of oxygen from the chloride, the gas bubbles noticed being due to air adhering to it. This was further proved by melting some blackened chloride in a retort, as well as by exposing some white chloride to a moderate heat till it blackened before melting. In both cases hydrochloric acid was evolved, but no oxygen. It appears, therefore, that light simply brings about the separation of a portion of the hydrochloric acid combined with the silver, and the same effect can be produced by heat. Another portion of white chloride set in a dark place in a current of air darkened almost as quickly as if light had acted upon it. The air, therefore, had caused the disengagement of part of the hydrochloric acid, which must escape if the chloride blackens, and this result can be brought about in various ways. We may note that Stahl (Anweisung zur Metallurgie, 1720) mentions this remarkable volatility of the precipitated chloride and its visible fuming and loss of substance when exposed to a strong current of air. In another work he also notes the darkening and volatilization of luna cornea when heated with access of air, and attributes the change of color to the action of sulphur.

Some experiments by the Abbé A. M. Vassali, described in two papers entitled "Parallèle de la Lumière Solaire avec celle du Feu commun," published in Vol. V of the Memoirs of the Turin Academy (1791–92), may be noticed. He shows that precipitated silver chloride can be darkened, though slowly, by the flame of a lamp as well as by solar rays; also that it could be slightly darkened by the light of the full moon, especially if it were concentrated by a lens. (This result was disputed by subsequent observers.) He concludes, therefore, that the light of the moon is the same as that of a flame or of sunlight, but not so intense. He used the chloride taken moist from a bottle and spread on unsized paper. In the second paper, he describes an experiment made to ascertain the loss of weight in the dry chloride after exposure to light, and how on concentrating the sunlight with a lens the chloride was partly reduced to metal.

MRS. FULHAME.

More closely connected with photography is the work of Mrs. Fulhame, as described in her book, An Essay on Combustion, with a view to a new Art of Dying and Painting, etc. (1794). She began her experiments in 1780 in making cloths of gold, silver, and other metals by chemical processes. She also prepared maps in which the rivers were shown in silver and the towns, etc., in gold, and it is evident

from this and from the title of her book that she had an idea of the graphic application of reducing solutions of silver and gold upon silk. It is surprising, therefore, to find that she does not seem to have thought of making patterns on her silken tissues by using stencils. She refers to Doctor Lewis's experiments, already noticed, and could have got the idea from his account of Schulze's experiment. There is, however, no mention of it, and she, like her predecessors, treated the question of the reduction of metallic salts or solutions by light almost entirely from its chemical side. Though at fault as regards her ideas of the nature of light, she made a great many very interesting experiments on the reduction of gold and silver by chemical processes, as well as by the action of light on pieces of silk treated with solutions of chloride of gold or nitrate of silver. She found that light had little or no action on them when they were carefully dried before exposure, while if they were moistened with water, the metal was very easily reduced. She concluded, therefore, that the presence of water was necessary to effect the reduction, as it also was in the case of other reducing agents she tried, including hydrogen gas, phosphorus, sulphur, and some of its volatile compounds, charcoal, acids, etc. The favoring effect of moisture in the case of the reduction of gold and silver by light, had, as we have already seen, been noticed by Du Fay and Lewis, but not investigated as it was by Mrs. Fulhame.

The account of her experiments with light is in the eighth chapter of her book (p. 142), headed "Reduction of Metals by Light." She first shows by experiments with strips of silk treated with solutions of nitro-muriate of gold and nitrate of silver, dried and suspended over water and kept in darkness for three months, that water alone has not the power of reducing metals at the ordinary temperature of the air. She then describes a series of parallel experiments with strips of silk treated with solutions of the same salts; (3 and 7) dried in the air and suspended in a window exposed to the sun for about three months, both showing considerable darkening and partial reduction, stronger with the silver than the gold; (4 and 8) dried and suspended in crystal phials over dry carbonate of potash, the phials being sealed with wax and exposed to the sun as before, both strips showing only a very slight reduction on the exposed side of the silk; (5 and 10) the slips after being dipped in the solutions of gold and silver were placed upon china plates and exposed to the sun, being kept wet with water during the exposure. In the case of the gold the color soon changed to purple and after an hour the silk was covered with a coating of bright reduced gold. With silver the silk also soon darkened and in four hours had acquired a blackish-gray color, but further exposure was required to show particles of silver on the under side of the silk; (6 and 11) the slips were dipped in alcoholic solutions of the gold and silver salts and

exposed in the same way on china plates, but kept moist with alcohol. In the case of the gold no change took place in an hour. The experiment was interrupted by want of sun, and on subsequent exposure there was a faint change of color and some reduced gold. With silver there was more darkening, up to reddish brown, but no blackening after four days' exposure. In (9) a slip of silk was dipped in alcoholic solution of silver nitrate and after very careful drying in darkness over sulphuric acid in a phial was exposed to light over the acid for about three months without the slightest change of color.

From these experiments she concludes: (1) That water is essential to the reduction of metals by light; (2) that light does not reduce metals by giving them phlogiston; nor (3) by fusing and expelling their oxygen; (4) light is a combustible body, for it acts like hydrogen, phosphorus, sulphur, and charcoal in the reduction of metals, and further, that it is obvious that light reduces metals by decomposing water attracting the oxygen, while the hydrogen unites, in its nascent state, to the oxygen of the metal and reduces it, forming at the same time a quantity of water equal to that decomposed. In chapter 10 she gives an intelligent explanation of the decomposition of water which takes place when silver is precipitated in the metallic form by iron and other metals, the precipitant uniting with the oxygen, while the hydrogen combines with the oxygen of the precipitated metal, forming water, and reduces the metal.

These principles are applicable in the same way to the reduction of silver by acid iron solutions, as in the wet collodion process. She also notes the reducing power of gallic, tartaric, and formic acids on metallic salts. In considering her work it must be remembered that chemical science was in a very transitional state at the time she wrote, but it is interesting because it led to further investigation of the action of light on silver compounds by Count Rumford, Ritter, Berthollet, and others. Her little treatise was translated into German by Lentin, and favorably reviewed by Ritter. A very appreciative account of the experiments with light is to be found in Placidus Heinrich's prize essay, "Von der Natur und den Eigenschaften des Lichtes" (St. Petersburg, 1808, p. 106). We find several of her experiments repeated in a little book of chemical recreations (Rational Amusement, by W. M. Toulmin, Calcutta, 1822), among them methods of drawing silver or gold figures of flowers, etc., upon silken ribbons. Many of her observations were confirmed and extended by Count Rumford in a paper entitled "An inquiry concerning the chemical properties that have been attributed to light" (Phil. Trans. R. S., 1798), in which he tried to show that the reduction of the gold or silver on the tissues was produced, not by any chemical combination of the matter of light with such bodies, but merely by the heat which is generated or excited by the light that is absorbed by them.

BLACK.

In Dr. Joseph Black's Lectures on the Elements of Chemistry (2, 660), he has fully treated of the salts and best known ores of silver and discussed the action of light in changing the color of the chloride and permanently staining organic and mineral substances moistened with the nitrate. His explanation is similar to Doctor Lewis's, and he says those bodies to which the solution is applied attract the acid from the calcined silver, while at the same time this metal is restored to its metallic state, or made to approach that state, by the action of the light, which expels from the calx a quantity of vital air. This effect of light in this and other similar examples is well known by experience, but it is not clearly understood how it is produced. Of the chloride he says that if perfectly dry and white it will not change its color in air that is also perfectly dry, although accessible to light, and then he discusses Scheele's and Berthollet's experiments upon it. These lectures were written before 1796.

WILLIAM HERSCHEL AND RITTER.

In 1800 William Herschel, following somewhat in the footsteps of Senebier, discovered the heat rays beyond the visible red rays, by means of thermometrical observations, and this discovery was followed in 1801 by the almost more important one, so far as photography is concerned, made by J. W. Ritter of the invisible ultra-violet rays and of their strong chemical action upon salts of silver. The first account of these results appears in an extract from a letter from Herren Ritter and Böckmann, in Gilbert's Annalen, Volume VII, 1801, page 527, discussing Herschel's results. He (Ritter) says: "On February 22, I also came upon solar rays on the violet side of the color spectrum and beyond it, and indeed proved it by means of horn silver. They reduce even more strongly than the violet light itself, and the extent of these rays is very great." A further communication was made in the Erlangen Literatur Zeitung, 1801, No. 16, page 121, and a complete account of the investigations was given in a paper read before the Jena Society for the Investigation of Nature, in the spring of 1801 (reprinted in the collected works of Ritter, Physisch-Chemisch Abhandlungen, II, 81). It is entitled "Remarks on Herschel's recent researches on light," and is a most interesting paper, more so as regards the chemical action of the red and violet ends of the spectrum than for any photographic application.

As the thermometrical method used by Herschel for showing the extension of the spectrum at the red end would have been useless in investigating an extension of the violet end, where changes of temperature are not indicated, Ritter, noting Scheele's observation that horn silver, or muriate of silver, darkened much more rapidly in the

violet than in any other ray of the spectrum, followed his method. A strip of strong white paper was coated very evenly by means of a brush with precipitated silver chloride finely rubbed down with water into a semifluid magma. When exposed moist in a dark room to the solar spectrum of a prism, it at once quickly darkened at a considerable distance beyond the outer violet, then in the violet itself, and finally showed the weakest action in that part where the blue loses itself in the green. Through the yellow and red and on beyond, the chloride remained white, however long it might be exposed.

This experiment, he says, shows the presence of invisible rays beyond the violet in continuation of the visible rays, and possessing the same action, and that, just as is shown at the red end by the thermometer, their maximum action lies beyond the limit of the visible rays and at a considerable distance from them. In the same way as the heating action shown by the thermometer is almost confined to the red end of the spectrum, so the darkening action on the chloride is almost entirely confined to the blue and violet. He remarks that Scheele must have made his observation very casually not to have noticed that in half the spectrum there was no action at all, and it is to be regretted that he overlooked this fact and the physical and chemical phenomena connected with it.

He then discusses the chemical nature of the change in the horn silver, which consists of muriatic acid and silver oxide (silver and oxygen). By the blackening of this substance the silver loses its oxygen, and, since it can not remain combined with the acid, reverts to the metallic state, appearing black on account of its being finely divided. Consequently what occurred on the blue side of the spectrum was deoxidation, one of the two great processes into which every chemical reaction finally resolves itself. Its opposite is oxidation. Seeing that the deoxidation took place only at the blue end of the spectrum, the question was whether corresponding oxidation took place at the red end. He set himself to prove it by exposing a strip of paper coated with the chloride, but already evenly darkened in the violet or other part of the blue end, so that the red rays fell on the darkened part, comparing it from time to time with a similarly darkened strip. He found that near the red and beyond it there was a place at which the darkened strip became distinctly paler, and it gradually spread till, after a quarter of an hour, the middle of the spectrum had retained its original tint, which became gradually weaker until it almost disappeared at a point beyond the red and then increased again for a short space.

From this he argues that the loss of color in the darkened chloride was due to oxidation of the silver, and that therefore the red rays have oxidizing properties, agreeing very closely in gradation with that of the rise and fall of temperature in Herschel's experiments.

Thus the whole prismatic spectrum acquires a new dignity as chemical. In white light, both forces, oxidation and the characteristic deoxidation, are in a state of opposite combination. The whole spectrum is divided into two parts, the sphere of the one toward the red being oxidation, and of the other, toward the blue, deoxidation.

In a third experiment a long, darkened strip of the chloride paper was placed in the spectrum for five or ten minutes, when the outer ends of the strip were found unchanged; but the whole blue and violet side had darkened, the maximum being beyond the visible violet rays, as in the first experiment. The whole of the red end, on the contrary, became lighter, and the maximum bleaching action was, as before, beyond the visible red rays. Similar results were obtained by exposing a strip of the white chloride paper in a bright light and at the same time throwing the spectrum upon it.

After discussing the relative oxidizing and deoxidizing powers of the two ends of the spectrum and expressing his desire for exact measurements of the intensity of the energy of the various rays throughout the spectrum, as well as of its extent, he says that in chemistry it is known that water is the chemical medium in all processes of oxidation and deoxidation by the wet method. By it alone can the oxidizable be oxidized and the oxidized deoxidized, and in both cases decomposition of the water takes place. In the first case the oxygen combines with the oxidizable body and the hydrogen is set free or combines with any oxygen present in a free or combined state to form water anew. In the second case the hydrogen of the water combines with the oxygen of the oxidizable body to form water, while the oxygen formerly combined with the hydrogen of the water goes to the oxidizable body present, the deoxidation of which it usually only indirectly brings about. The active agent in the first is therefore oxygen, and in the second is something which possesses the same strong affinity for oxygen as hydrogen, or is hydrogen itself. He gives as a parallel the decomposition of water by electricity or magnetism. In a later paper he completes the parallel by showing that if the two poles of a voltaic pile are placed in half-blackened silver oxide or chloride the negative pole increases the darkening, while the positive entirely prevents it. Perfectly dry horn silver appears to remain perfectly unchanged in sunlight in consequence of the want of water to be decomposed and supply the hydrogen necessary for the reduction. In this theory of the action of water he quite supports the theory put forward by Mrs. Fulhame. The fact that perfectly dry silver chloride exposed in a vacuum remains white has been proved by Sir William Abney.

Although it appears from a later paper that Ritter saw how important his results would be in connection with the action of light on organic bodies, it is curious that he made no similar experiments with

resinous and other organic substances shown by Senebier to be sensitive to light. He makes no mention of Senebier; but, had he known of his work, he would probably have done so, as he recognized that all bodies were more or less sensitive to light.

Ritter must have been one of the first to recognize the electrical nature of sunlight and the unity of principle in the polarity of chemistry, electricity, magnetism, and heat. I can not now dwell upon this aspect of his work, but in the light of modern physico-chemical science it seems worthy of attention.

DOCTOR WOLLASTON.

The existence of the ultra violet rays was also noticed by Dr. J. H. Wollaston in 1801, about the same time as they were observed by Ritter. In a note to a communication to the Royal Society (Phil. Trans., 1802, p. 379), he says:

> Although what I have above described comprises the whole of the prismatic spectrum that can be rendered visible, there also pass on each side of it other rays whereof the eye is not sensible. From Doctor Herschel's experiments (Phil. Trans., 1800) we learn that on one side there are invisible rays occasioning heat that are less refrangible than red light, and on the other I have myself observed (and the same remark has been made by Mr. Ritter) that there are likewise invisible rays of another kind that are more refracted than the violet. It is by their chemical effects alone that the existence of these can be discovered, and by far the most delicate test of their presence is the white muriate of silver.
>
> To Scheele, among many valuable discoveries, we are indebted for having first duly distinguished between radiant heat and light (Traité de l'Air et du Feu, secs. 56, 57), and to him also we owe the observation that when muriate of silver is exposed to the common prismatic spectrum it is blackened more in the violet than in any other kind of light (sec. 66). In repeating this experiment I found that the blackness extended not only through the space occupied by the violet, but to an equal degree and to about an equal distance beyond the visible spectrum, and that by narrowing the pencil of light received on the prism the discoloration may be made to fall almost entirely beyond the violet.

In a subsequent communication to Nicholson's Journal (Vol. VIII, 1804, p. 293), he explains that in the above note he was careful to express the power exerted by the most refrangible rays on muriate of silver in general terms as chemical, not merely from a doubt whether they would in other cases produce a corresponding effect, but because he had at that time made experiments which proved that the same rays which cause the emission of oxygen by muriate of silver occasion its absorption by the resin usually called gum guaiacum, which turns green by absorption of oxygen when exposed in the air to sunshine, and consequently he objected to Ritter's designation of the ultra violet rays as disoxidizing.

He adopted an ingenious method of obtaining prismatic images for the purpose of his experiments, and in this way must have been one of the first to produce a photographic image on silver chloride by means

of a lens. Over a lens seven inches in diameter and about twenty-four and one-fourth inches focus he pasted a circular piece of paper having its radius one-tenth of an inch less than that of the lens, thus leaving a prismatic annulus corresponding in the length of its circumference to a prism twenty-two inches long, so arranged by its circular form that any one of the colors might at pleasure be brought to a focus, or the spectrum could be received on a ring of any diameter required by mere variation of the distance of the lens. At short distances the exterior margin of the spectrum was red and the violet within; at greater distances than the focus the order of the colors was reversed, the violet being on the margin and the red within. With this apparatus he found that the effect on muriate of silver was much accelerated. At distances short of twenty-two and one-fourth inches a ring was produced, at twenty-two and one-half a circular dark-colored spot, and at about twenty-three inches appeared to be the focus of these rays, as the spot was then smallest; at twenty-three and one-half it was larger, at twenty-four and one-fourth it again became a ring shaded to the center, and at twenty-four and one-half (unless the paper had been wetted) the center remained completely white, though strongly illuminated. He was, however, unable to restore the white color to the muriate after it had once been tinged, however slightly, by exposure to the most refrangible rays. Similar experiments were tried with the gum guaiacum on paper tinged with an alcoholic solution of the gum.

THOMAS WEDGWOOD.

We now come to Thomas Wedgwood's experiments. Though they may have been carried out some years before they were published, I have thought it better to discuss them in order of the date of their publication by Davy in 1802. Miss Meteyard mentions (Life of Wedgwood, 2, 586) with regard to Thomas Wedgwood's early work: "His father early in 1774 had used the camera obscura for taking views for the Russian service, and Doctor (Matthew) Turner, of Liverpool, as it was well known, had either invented or brought to tolerable perfection the art of copying prints upon glass by striking off impressions with a colored solution of silver and fixing them on the glass by baking on an iron plate in a heat sufficient to incorporate the solution with the glass. With knowledge thus obtained and observation directed, it amounts to absolute certainty that Thomas Wedgwood, during some of his experiments on the production of light from different bodies by heat and attrition, made certain discoveries which led practically to the first principles of photography." She goes on to discuss his subsequent experiments with Davy and the difficulty of fixing the images, and falls into the mistake about the two

early photographs, supposed to be by T. Wedgwood, which were brought before this society in 1863, and are now in the society's collection. Where she got the information about Dr. Matthew Turner's burnt-in silver prints she does not say, and I have not been able to find any other reference to them.

We find, however, that the intimacy between Doctor Turner and the Wedgwoods began in 1762, and afterwards that he compounded varnishes, fumigations, bronze powders, and other chemical appliances for Josiah Wedgwood. In a letter from Wedgwood to Bentley, about 1767, he says: "One of the fumigations is a most excellent enamel color—so fine a yellow that I have some hopes of the great work being perfected, and that we shall be able to turn even the dirt under our feet into gold." Now there is a great deal about glass staining with silver and other yellow enamels in Doctor Lewis's Philosophical Commerce of the Arts (1763) already noticed, and it is quite possible that Doctor Turner may have used this source of information. There is evidence to show that T. Wedgwood was engaged in experiments on the reduction of silver for the ornamentation of pottery about 1790. Miss Meteyard says (op. cit., ii, 585): "To solve some problems connected with light he used silver differently prepared, and his observations thereon led to the invention of what was termed 'silvered ware,' namely, a pattern of dead or burnished silver upon a black earthenware body. We first hear of this ware in 1791." She gives an engraving of a tea tray ornamented with patterns which could easily have been obtained from stencils, and it may be noted that whereas the previous experimenters in this direction had mostly been chemists, young Wedgwood had very strong artistic instincts, and being accustomed to prepare designs for pottery would more naturally be led to the pictorial application of the old methods of obtaining images by the reduction of silver salts. There was no discovery of any new principle in this reduction, but the application of it to copying drawings on paper by contact or in the camera was a distinct and marked advance toward practical photography of which the whole credit is undoubtedly due to Wedgwood. We find confirmatory evidence that silver pictures were being made about this time in a letter from James Watt to Josiah Wedgwood, written apparently in 1790 or 1791, and beginning thus: "Dear Sir: I thank you for your instructions as to the silver pictures, about which when at home I will make some experiments."

There is some doubt about the date of this letter, Mr. Litchfield putting it as above (Tom Wedgwood, p. 186), while Miss Meteyard notes it as docketed "Hand Mill—1799" (Group of Englishmen, p. 150) and says it was written a few days after Watt visited Etruria, in 1799, on business connected with a hand mill. From correspondence with Leslie, moreover, it seems probable that the early experiments were

resumed about this date or in 1800. Writing to T. Wedgwood in November, 1800, Leslie mentions an object glass for the solar microscope and some painted glass which had been left for him at the Wedgwood House, in York street, St. James square, and Wedgwood came to town about the same time. Davy could not have taken part in these experiments, because he was still at Bristol, but they were old acquaintances, and Davy may have advised him. In Wedgwood's earlier experiments of 1790 he no doubt had the assistance of Chisholm, who, as we have seen already, knew a good deal about the reduction of silver and other metals by light. Davy mentions in the paper published in the Journal of the Royal Institution for 1802 that to copy the images formed by means of a camera obscura was Wedgwood's first object in his researches, and for this purpose he used the nitrate of silver, which was mentioned to him by a friend as a substance very sensible to the influence of light, but the images thus formed in the camera were too faint to produce any effect on the nitrate of silver, and all his numerous experiments to this primary end proved unsuccessful.

From the scanty details of the experiments given by Davy in this paper it is very difficult to ascertain clearly the relative share that Wedgwood and Davy had in producing the results obtained. It is evident from the above that the idea of reproducing the images formed in the camera obscura was Wedgwood's own, for he had been familiar with the use of it from his youth, and his first experiments were no doubt made with paper washed over with a solution of silver nitrate. For certain subjects, copying paintings on glass, or making delineations of objects partly opaque and partly transparent in texture, such as leaves, or wings of insects, etc., white leather was found preferable to paper, because it was more sensitive, the tanned gelatine no doubt acting as an accelerator. Davy, however, says that in following these processes he found that the images of small objects produced by the solar microscope might be copied without difficulty on paper, but it was necessary that the paper should be but a small distance from the lens. He notes also that the muriate of silver was more sensitive than the nitrate and both were more readily acted on when moist than when dry, a fact long known. The advantage of the nitrate was its solubility, but leather or paper could be impregnated with the muriate by diffusing it through water and applying it in this form (as Ritter did) or by immersing paper moistened with the solution of the nitrate in very dilute muriatic acid.

In discussing the difficulty of preventing the uncolored parts of the copies or profiles from being acted on by light, even after repeated washings, on account of some of the saline matter still adhering to the white parts of the paper or leather and causing them to darken on exposure to the sun, he says, "It is probable that both in the case of

the nitrate and the muriate, a portion of the metallic oxide abandons its acid to enter into union with the animal or vegetable substance, so as to form with it an insoluble compound. If so, it was not improbable that substances might be found capable of destroying this compound either by simple or compound affinities. He had imagined some experiments on the subject and hoped to publish them later." In conclusion he says: "Nothing but a method of preventing the unshaded parts of the delineation from being colored by exposure to the day is wanting to render the process as useful as it is elegant." From this it is very evident that he fully appreciated the value of the process if only the difficulty of rendering the images permanent could be overcome.

It is easy to understand that the want of sensitiveness on the one hand and on the other the difficulty of fixing the images were sufficient to render Wedgwood's original idea of reproducing objects in the camera quite impracticable with papers prepared with the nitrate or chloride of silver. Davy does not mention having tried any chemical method of fixing beyond repeated washings. In the case of the nitrated papers, washing with warm distilled water should have been sufficient to render the pictures fairly permanent; but it would not answer with the muriate, for which the only method available at the time would be treatment with solution of salt or of ammonia, both of which are unsatisfactory. Davy, being well acquainted with the previous work of Scheele, as is shown by his note in the paper, would have known of the solvent action of ammonia on the unexposed chloride, but, as Berthollet showed, it also attacks the exposed and darkened parts. Robert Hunt says it can be used effectively as a fixing agent for silver chloride or nitrate prints, but requires very great care in its use to avoid the solution of the reduced image. With chloride prints on paper prepared as described above, without any free silver, by brushing on the chloride (Talbot seems to have been the first to use the method of preparing the muriated paper by double decomposition with excess of silver) I found that the image was weak and only loosely adherent to the paper.

After treatment with dilute solution of ammonia the coating dissolved off, leaving a faint gray image, formed, as Davy describes, by the combination of some of the silver with the organic material of the paper. A 10 per cent solution of common salt did not have the same solvent and clearing action as the ammonia, and the paper darkened again readily in the light. The solvent action of hyposulphite of soda on salts of silver was not known till 1819, when Sir John Herschel first drew attention to it. Under these circumstances one can not be surprised at Davy not following up the subject, he being fully occupied with his Royal Institution lectures, besides investigations and researches of greater importance at the time. He published the results of Wedgwood's invention with his own observations, as far as

they went; and had he not done so, it is doubtful whether tnere would have been any record of them at all, and Wedgwood would have lost all the credit that has always been considered justly due to him of being the first to apply the well-known reduction of salts of silver by light to the reproduction of pictures and natural objects either by contact or in the camera. Like so many other discoverers, he was before his time, and it must be agreed that there is an immense gap between these imperfect and unsuccessful trials and the brilliant practical results achieved some years later by Daguerre, Reade, and Talbot, with the more sensitive iodide of silver, the use of which, it must be recollected, was rendered possible by Davy's investigation of Courtois's discovery of iodine, and Herschel's, of an efficient and suitable fixing salt. To this ultimate success Wedgwood's early trials with the camera no doubt contributed as embodying the first idea of practical photography of natural objects and demonstrating its possibility.

At this point I must conclude my sketch. Although during the intermediate period, between Wedgwood, in 1802, and Daguerre and Talbot, in 1839, no marked progress was made in practical photography, immense strides were made in the chemistry and optics connected with it, so that it was gradually being made possible and practicable. A record of these advances would appropriately form another chapter in this history.

THE RELATIONS OF GEOLOGY.[a]

By Prof. Charles Lapworth, LL. D., F. R. S.

We stand to-day, gentlemen, at the beginning of a new century. The science of geology, whose devotees we are, is one of the youngest of the great family of the sciences. The years since first it became conscious of its being are but few in number, and its struggle for existence has from the first been incessant. Yet I doubt not that there are many observers familiar with its history who would assert that "young as it is in years, it is already old in achievements, and that the roll of its discoveries and the number and extent of its conquests stand almost unrivaled for their far-reaching influence upon the philosophy and the practice of mankind."

But it is neither necessary nor dignified on our part here to-day to advance or even suggest this claim. For it is not our self-esteem which prompts our work, or the applause of the world that cheers us in its pursuit. Rather is it the delight in the work itself which animates our labors; and it is in the sympathy and the appreciation of our fellow-workers that we rejoice when our aim is achieved. To geology and geologists do we stand or fall.

That being so, I have asked myself, as your elected representative, whether it would not be good for us, as a united family of geologists met here together at the close of one era and the opening of the next, to take stock, as it were, of the work which geology has already accomplished, and note how we are prepared to face the tasks which the new era will demand of our science and of ourselves.

But self-centered though we may be as individual geologists, and self-centered though we may consider our science, we share the common lot of all men, and our science shares the common lot of all the sciences. As individuals we receive from our fellow-men all that makes for our social well-being, and our science owes its very existence, and most of the conditions that make for its progress, to the aid and sympathy afforded by its fellow-sciences.

We have, therefore, no right to make this prospect or retrospect in the family privacy of our own science without regard to the feelings

[a]Anniversary address by the president to the Geological Society of London, February 20, 1903. Reprinted from the Quarterly Journal of the Geological Society, vol. 59, part 2, May 22, 1903, pp. lxvi–xcix.

or the claims of others. Geology has not only its privileges, but also its duties, and the entire world of science and practice has the right of demanding a justification of the faith that is in us. Nor do I think that it asks two much if it insists upon a categorical answer to the questions, What is this geology of which we are so proud and so confident? What has it done for the mental or material benefit of the human race? and on what grounds does it justify its claim to respect and support as one of the factors in the advance of humanity?

Far be it from me to presume to attempt to reply on your behalf to questions of so serious an import. That task must be left in part to the eloquent apologists of our science and in part to the results achieved by the great workers in geology—results that carry the answer with them. But on an occasion like the present I doubt whether we can do anything better or more appropriate to the time than have a quiet but open talk together over the position and relations of our science.

I.—Geology and its Fellow-Sciences.

GEOLOGY AND ASTRONOMY.

In the words of one of the most devoted adherents of our science, we might say, "without impropriety, that all the physical sciences are included under two great heads—astronomy and geology; the one comprehending all those sciences which teach us the constitution, the motions, the relative places, and the mutual action of the astra, or heavenly bodies, while the other singles out for study the one astrum on which we live, namely, the earth."

This definition, if we may call it so, is one which is not only simple and convenient, but it gives perhaps the broadest and clearest view of the place and mission of geology, regarded from an outside standpoint. And there is a naturalness in this association of geology and astronomy which can not be ignored.

Astronomy concerns itself with the whole of the visible universe, of which our earth forms but a relatively insignificant part; while geology deals with that earth regarded as an individual. Astronomy is the oldest of the sciences, while geology is one of the newest. But the two sciences have this in common—that to both are granted a magnificence of outlook and an immensity of grasp denied to all the rest.

Yet, compared with other sciences, few perhaps have so small a number of adherents and working members. It may be that this is due to the opinion of the majority both of the past and the present generation that these two sciences seem to demand for their successful prosecution an abnegation of emotion and of all human sympathies; their grandest results are not the conquests of the heart, but of the head, wrought out in the cold, dry light of reason.

It is needless in these days to insist upon the fierce and pained resistance which both have encountered at almost every fresh advance. In spite of the fact that in the end every such advance has proved itself to be a higher stage in the mental or material progress of mankind at large, there still exists, even at the present time, an instinctive antagonism to astronomy and geology in the minds of many, especially from the sides of literature and of philosophy.

The bewildering immensities of space and time with which these two sciences deal, and their insistent claim to be the only authorities that can bring home to the mind of man the awful ideas of infinity and eternity, cause them to be shunned and dreaded by the man of letters, and wring now and again a wail of impotence and sadness from the poet:

> What be these two shapes high over the sacred fountain,
> Taller than all the muses, and higher than all the mountain?
> On these two peaks they stand, ever spreading and heightening.
>
> * * * * * *
>
> Look in their deep double shadow, the crowned ones all disappearing!
> These are Astronomy and Geology—terrible Muses!

But, while astronomy and geology share almost equally in the vague dread which they inspire in the minds of those who look only at nature from the side of the emotional and the beautiful, they by no means share equally in the admiration instinctively accorded by the average thinking man to the sciences in general. Along the whole range of the concrete sciences there is perhaps not one that has so effectually compelled the respect of men as astronomy. There is not one in whose progress they have taken so keen an interest, or whose conclusions have been so unhesitatingly accepted. On the other hand, every new discovery arrived at by geology appears to have come upon the minds of men with something of the nature of a shock. The conclusions of our science seem rarely or never to have been accepted with pleasure because of their value or their grandeur, but rather to have been adopted with reluctance and regret and because they were found to be irresistible.

Yet, after all, this is hardly a matter for astonishment, for it has its root in the origin and the growth of the two sciences themselves. Astronomy had its birth in the childhood of mankind, in the silence and calm of the night, and in the wonder of curiosity and awe. It carried with it from the very first the mystic fascination of the distant and unknown. It was associated in man's mind with the peaceful hours of rest and of contemplation. It held within it much of the enthusiasm and elevation of religion, for it lifted man's eyes upward and heavenward, away from the never-ending struggle in the world below.

Geology had none of these attractions. The world over which early man wandered was to him the theater of a never-ending conflict, in

which were arrayed against him impassable seas, unscalable mountains, gloomy forests peopled by deadly beasts of prey, raging streams and foaming torrents, each and all the haunts of spirits luring him to doom.

What wonder, then, that astronomy was one of the first of the sciences to come into being, and that the successive generations of mankind have mingled with an awe of her greatness a tender and respectful appreciation of her work and of her results?

And it was but natural that geology should be nonexistent until long after most of the other sciences had come into being and some had grown almost to maturity. Even when she at last appeared and thrust herself, as it were, into the established aristocracy of the sciences, she brought with her the stigma of her lowly origin. And to that she added much of the recklessness and assurance of youth and a bewildering absence of respect for the settled conventionalities of opinion and tradition. This is no excuse; but it is in its way a reason why she is still supposed to be somewhat of a parvenu among the sciences, and is often only listened to with patience because of her powers and her genius.

But there is also another reason for the reluctance with which the conclusions of geology are received by men in general, when compared with the reception accorded to those of astronomy, namely, the relative backwardness of the race in its appreciation of the concept of the extension of time as compared with its advanced appreciation of the concept of the extension of space. Note the willingness, and even the welcome, with which any average audience of the present day accepts the statements and sympathizes with the conclusions of an astronomical lecturer who demands for his remoter starry distances, it may be, myriads of millions of miles. Compare that reception with the coldness, or at all events the smiling incredulity, of the same audience when a geologist suggests for the development of all the geological formations at the very most a hundred millions of years. But it is not only the popular audience, but also the majority of the men of education and experience, who still feel this curious hesitation and difficulty. And nothing perhaps has so retarded the reception of the higher conclusions of geology among men in general as this instinctive parsimony of the human mind in matters where time is concerned.

Yet, after all, perhaps this is easily accounted for. It has been well said that "the intellectual advancement of men is due to the relatively small effects of individual experiences added to the large effects of the experiences of the antecedent individuals." The concept of the vastness of space has been familiar to mankind for untold ages, and has grown and expanded with the growth of the race. The concept of the immensity of time has entered so little into the intellectual development of mankind has a whole, and in its grander aspects so recently, that the race is as yet incapable of adequately grasping it.

The wanderings of early man from place to place and land to land soon familiarized him with the idea of the extension of space. He had learned by bitter experience, times out of number, that the distant horizon which to the eye bounded the vast canopy of the sky above him was no boundary at all, but shaded away in all directions into a limitless world beyond, whose practical infinity had been proved to him by his own wanderings, and by those of his forefathers generation after generation. Thus the idea of the vastness of space had already become a part of man's intellectual equipment long before the origin of astronomy itself. And this idea has been deepened, broadened, and strengthened during the successive centuries of progress by the employment of constantly improving instruments of accurate measurement, by the invention of the telescope, the discoveries of geography, and by the application of the higher mathematics to astronomy as a whole.

But early man (and, indeed, his successors even down to and beyond the Middle Ages) was miserably provided with the experiences which might bring home to his mind the immensity of time. Early man himself had for his longest trustworthy chronological base line a short seventy years—the span of his own existence—or at most, perhaps, a hundred years, if he included the experience of his parents. Even in classical times all the past was to his experience vague and indefinite. He had, it is true, mythical traditions of heroic ages, golden ages, and the like, but these when summed up were merely the legendary total of the experiences of but a few generations. Bound down as was man's mind by his anthropomorphic ideas, he naturally assigned to the earth and mankind a correspondingly brief existence; a few generations—a few centuries at the most—must have witnessed its birth; a few generations more must inevitably bring about its death and disappearance. Even since the invention of letters and the compilation of accurate historical records the period of time of which man possesses experience, either personally or collectively, is at most a very few thousands of years. It is hopeless to expect, therefore, that for a long period to come the geological concept of the immensity of past time will permeate the minds of the many, or that they will accept the conclusions of geology, where time is concerned, with the same confidence as that with which they have long since accepted the conclusions of astronomy.

But this intellectual backwardness of the race in the matter of the appreciation of the vastness of geological time is not only a stumbing block in the way of the acceptance of the results of geology among the public at large, but also to the workers in other sciences, and even to the students of geology itself. It is well within the memory of many of us how even those holding the most advanced views in other sciences were intensely reluctant to acknowledge the possibility of the

existence of man upon the earth for more than a few thousands of years. And among the geologists of the preceding generation the demand of the so-called "uniformitarians" for those vast æons which must be granted if the geological formations were accumulated and deposited at the same rate as corresponding accumulations are brought together at the present day, was only reluctantly conceded by the majority after years of conflict and denial. Even at the present time it is the habit not only of eminent physicists, mathematicians, and chemists, but also of some of our geological authorities, to scout all reasonings that suggest a geological antiquity for our globe of more than a few millions of years.

Far be it from me to suggest that geologists should be reckless in their drafts upon the bank of time; but nothing whatever is gained, and very much is lost, by persistent niggardliness in this direction. The astronomer, although persuaded of the possible infinity of the universe, is just as careful in estimating the length of his grander base lines of millions of miles as is the geographical surveyor who takes years, it may be, to measure accurately the length of a base line a few miles in extent before he commences the triangulation of a single country. But the consciousness of the astronomer of the practical infinity of his realms gives him a freedom of action in dealing with space which is delightful. In the same way the geologist, who is blest with an assured conviction of the immensity of geological time, moves with an ease and freedom from cause to effect wholly denied to those wanting in this conviction. No doctrine in geology has resulted in such brilliance of discovery as the doctrine of uniformitarianism, which sets no theoretical bounds either to the efficacy of present causes or to the duration of past time. It is not, however, the eternity of geological time that this doctrine demands, but the assumption of the vast duration of the geological periods of which it has been made up. And if to this assumption the geologist adds the conscientious accuracy of the geodesist and astronomer, and not only takes for possible, but absolutely demonstrates by discovery after discovery the true extent of the æons that have gone to the making of the geological formations, he is certain to foster and eventually to establish in the minds of men a full and adequate conception of the immensity of geological time.

GEOLOGY IN PARTICULAR.

I have said that the widest definition of geology is that it is that science which, leaving to astronomy the study of the heavenly bodies as a society, devotes itself to the study of the earth as an individual; in other words, that it is a "geonomy" as contrasted with an "astronomy." But while this description is justifiable in principle, it is open to the natural objection that it shares this earth-knowledge

with many other sciences, especially with the science of geography. Perhaps the shortest definition that has been made of our science, and one equally acceptable to its students and to those who view it from the outside, is that geology is the "science of the structure of the earth. It is in and around that earth structure that all geological ideas center. In working out the solutions of the problems presented by that structure, geology not only finds her own special and peculiar mission, but extends a hand to all her sister sciences.

In studying the solid elements of that structure, geology shades through the science of mineralogy into that of chemistry. In the study of the changes which the parts of that structure have undergone and are now undergoing it shades through the science of meteorology into that of physics. In the study of the successive surfaces of that structure it grades into the science of geography. In the study of the stony relics of the vanished beings that once dwelt upon those surfaces it joins hands with the sciences of zoology and botany. In studying the phenomena presented by the sequence and interrelations of the rock formations which go to the building up of that structure, it finds the means of reading the past history of the earth and its living inhabitants—a glory reserved for geology alone.

It was not until geologists discovered that the solid earth crust had a structure which was made up of definite parts or "formations" capable of individual recognition and description, each showing a special distribution in space and in time, and each marked by characteristic features capable of being compared, contrasted, and reasoned about, that the science of geology attained individuality and became worthy of its name. It was this discovery—inaugurated by Lehmann and Guettard about the middle of the eighteenth century, made famous by Werner and his contemporaries toward its close, and established beyond all dispute by William Smith at the dawn of the next that gave geology a claim to be regarded as one of the concrete sciences, and placed in her hands the weapons with which she has fought her way onward irresistibly to the conquest of her kingdom.

Since the days of William Smith, the careful investigation and mapping out of these geological formations, igneous as well as aqueous, has spread outward from the original centers of investigation with extraordinary rapidity, until at the present day there is hardly a civilized nation that does not possess a government geological survey. The fascinating problems presented by these formations and the light which their solution has thrown upon all that concerns the past development of the earth and of its living inhabitants, have not only attracted hosts of enthusiastic students to the science itself, but have given it a far-reaching interest to countless workers in other branches of knowledge and opinion. As a consequence, there is hardly a single important intellectual center in the Old World or the New which has

not its own geological society, emulative of our own, whose members are either engaged in aiding the advance of that science or profiting by the benefits of that advance. One and all—national surveyors, members of geological societies, sympathizers in other sciences, collective bodies or isolated individuals—are united in a catholic freemasonary by their common study of, and interest in, the rocky structure of the earth.

I will not attempt the impossible by endeavoring to follow in detail the various stages in the development of geological science, or by trying to distinguish between what is due to the researches of its own students, and what is due to the aids afforded them by the fellow-sciences. But none among us would venture to deny the assertion that no branch of scientific inquiry has profited more than geology from what has been termed the "consensus of the sciences." No science has received more ungrudging assistance from other sciences, or has repaid more fully that assistance in kind. Almost every problem attacked by geology has needed the aid of some other branch of knowledge for its solution; almost every advance made by geology has furthered the progress of one or more of its fellow-sciences.

GEOLOGY AND MINERALOGY.

The discovery of the geological formations themselves may be said to have been essentially the outcome of the early association of geology and mineralogy. The brilliant ideas of Werner, embodied in his so-called "geognosy," in which these formations were first identified by their mineral characters, and then followed over their vast geographical extension until they were shown to stand related to the whole of terrestrial nature and of life, had unquestionably their root in mineralogy; and the geological student of the igneous formations is incapable of his task unless he is well acquainted with the latest methods and results of mineralogical science. But the idea of the inevitable association of mineralogy and geology must not be pressed too far, nor should it be allowed to give to the whole of geology that dominant mineralogical color in which it is often erroneously supposed to be steeped. It is impossible to overestimate the advantages which have accrued to the science of geology by its association with mineralogy. But that association is an alliance and not a conquest. Geology is not a province of mineralogy, but an empire in its own right, and between it and that of chemistry, mineralogy is, as it were, a kind of buffer kingdom having alliances with both.

But if geology owes much to its alliance with mineralogy, mineralogy has benefited by that alliance to quite as great an extent. Not only have all the minerals their home and habitat in the rock formations, but the mineralogist owes to the geologist all that he knows of their association and distribution. In no branch of our science has

mineralogy aided us more than in that of petrology, which has made such marvelous strides during the past generation; but that debt of obligation has been well repaid. To the petrologist is owing the discovery of the special association of the minerals in the igneous rocks, their relative order of generation, and their mutual interferences; and following upon this he has made known hosts of unexpected data rich in fascinating problems, opening out a new world of speculation and research both for the mineralogist and for the chemist.

GEOLOGY AND BIOLOGY.

But if geology owes the first suggestion of the geological formations and their individualization to mineralogy, she has received benefits of as long standing and of as great a moment from biology and biologists. The solid foundations of the paleontological side of geology were laid by the continental biologists, ranging from Steno to Cuvier, simultaneously with the discovery and the working out of the order of the geological formations. Nothing in the history of the growth of geology so astonished mankind or so effectually aided in lifting and dispersing the dark cloud of obloquy and neglect which hid from the world the magnitude of the results attained by the early geologists as the demonstration by the biologist that the extinct organic remains collected from the geological formations were identical in structure with creatures living upon the earth at the present day and that all these fossil forms fell naturally into a place in the accepted biological classifications. At every successive stage in the progress of stratigraphy since that time the geologist has been similarly indebted to the biologist for the interpretation and classification of his fossils; and when we have respect to the rarity and to the fragmentary condition of many of these forms, we can not sufficiently express our gratitude to biology for the aid which she has afforded us.

But there is no need to claim that geology has repaid the debt. It will be enough if I quote here two short receipts handed in on our behalf, one by the most distinguished biologist of the latter half of the century just closed, and another by the present occupant of his chair. In the words of Huxley, "The doctrine of evolution in biology is a necessary result of the logical application of the principles of the geological doctrine of uniformitarianism to the phenomena of life; Darwin is the natural successor of Hutton and Lyell, and the 'Origin of Species' the logical sequence of the 'Principles of Geology.'" These words were written by him about twenty years since, and his successor, in reviewing from a morphological standpoint a few months ago the work of zoologists accomplished during these twenty years, speaks as follows:

> The progress through which we have passed has produced revolutionary results; our knowledge of facts has become materially enhanced, and our classifications have

been to a large extent replaced in clearer and more comprehensive schemes; and we are enabled to-day to deduce with an accuracy proportionate to our increased knowledge of fact the nature of the interrelationships of the living beings, which with ourselves inhabit the earth. * * * Satisfactory as is the result, it must be clearly borne in mind that its realization could not have come about but for a knowledge of the animals of the past.

It is at the present day the habit of some to hint that paleontology, as geologists understand it, is a mere branch of biology, just as it was the fashion half a century ago to look upon it as a branch of geology. But the proper view, I take it, is to regard it as the common possession of both these sciences. Here, as in so many contests of opinion, the truth lies in the middle. It is undeniable that all the organic remains discovered by the geologist were in their day members of the great biological chain of life, and have, therefore, their individual places and relationships in the scheme of biological classification; and that as a consequence the study of their structure and their relationships falls within the province of biology. But it is equally undeniable that each of these creatures had an existence during a definite range of geological time, and that its fossilized remains occur at a certain horizon in the ascending series of the geological formations. They have thus a geological arrangement and grouping as inevitable and necessary as the biological one. While we grant that the biologist has not only a right but almost an obligation to place in its systematic biological position in his museum an example of every species hitherto discovered by the geologist, it is equally important for the advancement of science in general that the geologist shall have in his museum a stratigraphical grouping and chronological arrangement of fossil species always available for his geological work. There is a phylogenetic grouping by affinity for which the biologist is constantly striving, and to which he is daily more and more approximating; but there is also a chronological grouping by geological position, which for every individual specimen in the paleontological department of a geological museum was practically fixed the day when that specimen was collected from a known stratigraphical horizon. We may rest assured that year by year the stratigraphical classification in our geological museum will become more detailed and more refined. This chronological grouping constitutes a tool with which geology can not possibly dispense. Again and again in the years gone by the apparent sequence and the known paleontology have been in conflict as to the true stratigraphical position of local formations, and in every known case hitherto the paleontological side has scored the victory.

But, indeed, if we geologists were ever to become so benighted as to neglect this detailed sequential classification of the fossils in our museums, the biologists themselves would soon force it upon us for the sake of their own science. Fossils as thus arranged are and can be the only tangible proofs of the chronological order in which the

various types and forms of life made their successive appearance on the earth; and they are in consequence the clearest and most widely accepted evidences of the doctrine of biological evolution. And, further, the more minutely they are arranged in stratigraphical detail and the greater the number of species, varieties, or mutations which, are arranged under each horizon, the sooner will biologists have at their command the necessary materials enabling them to solve those great outstanding problems that bear upon the laws which have ruled in the origin, variation, and distribution of species.

GEOLOGY AND GEOGRAPHY.

Turning next to the relations between geography and geology, we may say, perhaps, that there are no two sciences more intimately connected or more mutually beneficial. I have already referred to the natural claim of some geologists that, logically, geology includes all that is contained in the study of the earth. But it might better, perhaps, be said that geology and geography share much of this collective study between them. Geology deals with the past of the globe and geography with its present—the former having, so to speak, the charge of its history, and the latter of its politics. The surface of the globe is their common limit, and in a way their common property. All that comes above that surface lies within the province of geography; all that comes below that surface lies inside the realm of geology. The surface of the earth is that which, so to speak, divides them and at the same time "binds them together in indissoluble union." We may, perhaps, put the case metaphorically. The relationships of the two are rather like that of man and wife. Geography, like a prudent woman, has followed the sage advice of Shakespeare and taken unto her "an elder than herself;" but she does not trespass on the domain of her consort, nor could she possibly maintain the respect of her children were she to flaunt before the world the assertion that she is "a woman with a past."

It is almost superfluous even to hint at the aid afforded by physical geography to physical geology, or to attempt to show how mutually dependent the two have always been one upon the other. At first geology was looked upon merely as a branch of physical geography. De Saussure, who first gave the name of geology to our science, was himself in the front rank of the physical geographers of his day. The study of the whole array of terrestrial phenomena described by the physical geographer is, if anything, even more necessary to the educational outfit of the young geologist than the study of mineralogy and chemistry. Without the aid afforded by the study of the present phenomena, which properly fall within the ken of the physical geographer, "the conquests of Hutton and Lyell would never have been achieved, and the true philosophy of geology would have been impossible."

Again, every advance made by the geographical surveyor in the accuracy and details of his maps has resulted in a corresponding improvement in geological mapping and surveying. Every advance made by the descriptive geographer in the discovery, delineation, and description of the geographical relief of continental lands or of the depths and deposits of the sea has increased geological knowledge, and has stimulated geological inquiry and discovery in an almost corresponding ratio.

But in this case of geography and geology, as in others, the benefits have certainly been mutual. Broadly speaking, almost the whole of that vast mass of information which geographers now possess respecting the work of those agencies which rule upon the dynamical side of physical geography has been wrought out and accumulated by geologists engaged in searching for the causes of geological action in the past. The grand processes of denudation, erosion, and deposition; the multifarious action of rain, rivers, and ice; the phenomena of earthquakes and volcanoes, and the rock-making activities of animals and plants were most of them first laboriously investigated by geologists, who welded them into tools for work in their own science and then handed them over bodily for permanent lodgment in the well-filled storehouse of the physical geographer.

As regards the surface of the earth itself, so numberless of late years have grown the visible and certain points of contact between the phenomena previously regarded as proper to the one or the other of the two sciences of geology and physical geography, and so evident to all has become the sequence of geological causes and geographical effects, that many geographers have of late years almost lost consciousness even of the existence of a possible downward limit to their science. Reveling in the wealth of geological facts and ideas already accumulated and lying ready to their hand, scientific writers have combined with their geographical description of the "forms" of the surface of the earth the geological explanation of their origins in that most interesting branch of knowledge which is sometimes named "geomorphology." This is undoubtedly a section of geonomic science which is of great value, and is destined to grow in importance as time goes on. But its study presupposes a preliminary education in which geology and geological causes take perhaps the largest share; and those who would class it merely as a subscience of geography are as wrong as those who class it merely as a subscience of geology. It is the healthy and vigorous child of both.

GEOLOGY AND PHYSICS.

Here we enter upon more difficult and dubious ground, namely, the relations of geology to the science of physics, especially in the matter of the so-called "hypogene" agencies. The mechanical modes and means of formation of our mineralogical rock sheets have long since

been recognized and agreed upon, but the mechanical modes and means of their deformation have, many of them, yet to be identified and established. In the matters of cleavage, jointing, and foliation we have advanced, and in the modes and effects of faulting we have already made some headway. But in the grander problems of orogeny, crust warping, and secular elevation and depression we are still very much in the dark. In spite of all the brilliant work which has been done of recent years, we are forced to acknowledge that we are still busied in collecting data upon which to found a philosophic system of crust deformation. Nothing yet formulated in this direction is of sufficient definiteness and breadth of grasp to afford matter from which anything more than suggestive deductions may be drawn by the higher physics and mathematics.

But although our materials are as yet too heterogeneous and too complicated to admit satisfactorily of such outside analysis, yet among geologists themselves there is being developed a tendency to assort and interpret them from two extreme points of view, which may perhaps be distinguished as the astronomical and the geonomical.

The working theory employed by the many at the one extreme is the collapse theory, which is founded essentially upon the (contraction) hypothesis of the gradual loss of heat of the earth's interior. This theory starts from the original covering of our globe, and regards the present state of that covering as that of a solid and more or less cooled crust, which warps, folds, and fractures as it follows down upon the slowly contracting, but still intensely heated (and probably solid), nucleus. This crust shows in its structure and in the major forms of the outer surface the combined effects of the radial and tangential deformations due to the contraction and collapse, these deformations being grouped about the remains of the chief irregularities proper to the crust at the time of its original consolidation.

The working theory employed by the few at the other extreme is the fold theory, founded essentially on the (undulation) hypothesis that the deformation may be largely due to tidal movements and to the constant redistribution of load and resistances. It starts from the known modes of deformation of the rock sheets which make up the present supercrust and of those of its superposed coverings of water and of air. It regards the earth crust as a spherical shell or bridge surrounding and balanced upon a fluid nucleus (probably gas-like), the shell being in a state of general vibration and its parts in a state of regional and local strain. This shell yields harmonically as a whole, and its various parts yield in groups or individually to the several stresses, but always in theoretic units (duads), each made up of two moieties which are the positive and negative equivalents of each other.

According to both theories, the type of deformation may be that of undulation, warping, folding, gliding, fracture, or flow, according as

the magnitude of the stress, the speed of the action, or the relative elasticity of the material may determine. Its development may range in time from that of an instant to that of an æon, and its extent from microscopic to hemispheric.

According to the first theory, however, the deformation is not theoretically symmetrical, but is consequent upon and has ever been controlled by the salient features of the original earth crust. According to the second, the deformation is theoretically symmetrical, and is due to the continual breaking down and readjustment of equilibrium; it is at every stage controlled by the length and direction of the instantaneous polar and equatorial diameters of the earth, and by the summational and individual deformations already effected.

The tendencies of the first theory are to compare all the phenomena of yieldage with those characteristic of solid bodies and to dwell especially upon the proofs of fracture (with the fault as the central type); to parallel such signs of symmetry as are apparent with that of crystals, and the loxodromic trend lines of the earth's surface with those of crystalline cleavage. The tendencies of the second theory are to compare the yieldage phenomena with those of flexible bodies (with the fold as the central type), grading on the one hand into those of rigid and on the other into those of liquid bodies, and including all types; to parallel the symmetries with those of wave forms, and to refer the trends to composition, interference, or superposition, as the case may be.

In the first theory there is inherent the expectation of continuous accretion and discontinuous collapse; in the second the expectation of rhythmic recurrence of form in space and of movement in time. According to the first theory the locus of the pole of the land hemisphere on or about the forty-fifth parallel is an accident of evolution and a survival; according to the second it is a theoretic necessity and a resultant.

How much of each of these views is a mere mental expedient, and how much is an expression of fact, must be left for future research to determine. The discovery of the true path lying between the two extremes will form one of the tasks which await the geologists of the coming era.

II.—Geology and Practice.

GEOLOGY AND THE USEFUL ARTS.

Up to this point I have dealt mainly with the so-called "scientific" aspect of geology, regarding it from the inside point of view as an interpreter of nature and a member of the great family of the sciences. But, as I have already hinted, we are bound also to consider it from the outside or "practical" point of view as being one of the

servants of mankind and an associate of the useful arts. Indeed it is wholly impossible to avoid dealing with it from this outside aspect. In the words of Herbert Spencer:

Not only are the sciences involved with each other, but they are all inextricably interwoven with the complex web of the arts, and are only conventionally independent of it. Originally the two were one, and there has been a perpetual inosculation of the two ever since. Science has been supplying art with higher generalizations and more completely qualitative previsions; art has been supplying science with better materials and more perfect instruments. * * * And all along this interdependence has been growing closer, not only between the arts and sciences, but among the arts themselves and among the sciences themselves.

I have already noted how greatly geology is indebted to her sister sciences, and how in every case the aid which she has been given has been fully reciprocated and the mutual sympathy broadened and enlarged. Surely there is no need for me to recall how deep and how fundamental are the obligations which geology owes to the arts in general, and to those of mining, engineering, and topographic surveying in particular. But it may not be without advantage if we geologists remind ourselves of that which in the absorption of our researches we are sadly prone to forget, namely, the existence of those many links that bind our science to the world of practice, and the vital need there is of strengthening those links by every means in our power.

It is true that the first duty of every science is to move incessantly forward from discovery to discovery along the straight path of unremitting investigation and research, following truth withersoever it may lead, wholly unbiased by the question as to whether that discovery bears any relation whatever to the material wants of mankind. But it is equally true that once a fresh fact has been discovered, or once a new and satisfactory conclusion has been reached, if that fact or that conclusion be of evident benefit to mankind at large, every lover of his science should welcome its utility and do his best to encourage its use.

Here, however, we can not ignore the fact that it is impossible that full use can be made of the results of any science until those to whom such results would be of practical value are educated at least in the principles of that science. And such education has a double value; it is not only of especial advantage to those who intend to make use of the results of the science, but it redounds to the benefit of the science itself, for it trains up a host of sympathetic students all concerned in its advancement.

We can not fail to recognize that those sciences—such as chemistry, physics, biology, and the like—which are generally acknowledged to be most intimately bound up with practice, and an education in which is held to be absolutely necessary for success in one or more of

the arts or professions, are the sciences which have the greatest number of students and are making the swiftest progress. It is the height of absurdity to imagine that geology can, any more than any other science, possibly restrict its activity to research alone. Rather may we say that the corporate geological organism has three necessary functions—research, practice, and education. So long as all three functions are naturally and healthfully performed, so long will geology live and flourish. Whenever either function remains long unexercised, or falls into disuse, there follows, of necessity, a weakness throughout the entire organism, which must in the end become lethargic and crippled, and fall behind in the race.

When, on the other hand, all three functions are most vigorously exercised, the progress of the science must be at its swiftest and its surest. And this fact has been well illustrated in the history of our science; for whenever these three functions of geology have been most clearly appreciated and simultaneously energized by its leaders, geology has shown forth with an especial and peculiar luster, and has won the attention and regard of the world.

Those who came from all parts of Europe to attend the lectures of Werner were drawn to him by his conviction that geology was one of the most useful of trainings, not only for the men of the mining and metallurgical world, but also for those who were interested in all that concerns man's relation to the earth in general. They listened with delight and with profit to the brilliant exposition of his far-reaching ideas, not only because they felt the fascination of these ideas, but also because they were impressed by his assurance of their material and intellectual utility. The geological education which they received from him they communicated in their turn to their own pupils, and rapidly spread the benefits and influence of geology far and wide over the economic and intellectual world of their time.

But we have even a more striking instance nearer home. I do not think that it is too much to assert that no single geologist whose name adorns the long roll of the past members of this society secured at one and the same time so far-reaching an influence upon the spread of geological knowledge at large, so sincere a respect for our science from the governments of civilized countries, and so kindly a regard and affection for it from the mass of mankind, as Sir Henry De la Beche. And I take it that all this was due to the fact that he, more than any other British geologist before him or after him, had a clear and well-balanced conception of the three functions of geology. He was at once a scientist, a practical man, and an educationalist.

No one familiar with his Geology of Devon and Cornwall or with his Geological Observer but will grant that he was, both from the side of research and of theory, a scientist to the backbone. But he was more than a scientist. He was a man whose life work had convinced

him that the useful side of geology is as important as the intellectual and, indeed, of the necessity there is for the constant union of science and practice, or, as he puts it himself, "Science and practice are not antagonistic; they are mutual aids." And mainly, perhaps because of this conviction, he was also a keen educationalist; for, as he himself expresses it, as "some reason, right or wrong, is sure to be assigned to every practice, it is most important for those connected with that practice that they should possess the existing knowledge upon which it rests."

De la Beche devoted some of the best years of his life to the task of convincing the Government and the people of this country of the importance of the knowledge of the science and practice of geology and its related sciences to the material and intellectual advancement of the nation. He brought round the Government of the day to his views, and the best minds of his time, from the Prince Consort downward, became his enthusiastic supporters. He created the British National Geological Survey, which has proved itself as beneficial to the advance of pure geology as it has to the development of the mineral resources of the Kingdom, while it has been the prolific parent of similar national geological surveys in almost all countries of the civilized world. He founded the Museum of Practical Geology as a national home for the collections made by geological research and for the illustrations of geology in all its practical applications, consecrating the building, even in its title, to that idea of the combination of knowledge and utility which justified the nation in its foundation and its maintenance. And more, he made that museum, through his genius and his knowledge of men, a living and growing center of instruction in geological science and its useful applications, selecting as the teachers of that special education some of the highest intellects of his day.

What other scientific leader of the nineteenth century can show so famous a roll of lieutenants? It is almost invidious to select names from the list. But so long as natural science, pure or applied, shall command the respect of men the names of Thomas Huxley, Lyon Playfair, Edward Frankland, John Percy, Edward Forbes, and Andrew Ramsay will be held in honored memory as those of men whose life work in science, or in practice, or in education, or in all three combined, place them in the front rank of the benefactors of their day and their generation.

We might go on to point out how the success of De la Beche's scheme caused it to outgrow rapidly the limits of its original home, for we are most of us familiar with the fact that while the geological survey and the national geological collections are still retained in the original museum, the educational sections became developed into the Royal School of Mines and eventually into the Royal College of Science, which in its turn practically became the center of that widespread

scheme of national instruction known as the "science and art department." But what especially concerns us here is that these results demonstrate, on the one hand, the naturalness and fertility of De la Beche's conception of the necessary association of science, practice, and education and, on the other, the far-reaching influence that geology and geologists have had on the extension and invigoration of scientific practice and education in Britain.

GEOLOGY AND ECONOMICS.

It is almost an impertinence to point out to an assemblage of geologists like this the relationships of geology and its applications to the material welfare of our fellow-countrymen; but those of us who are absorbed in the charms of research are now and again tempted to look askance at those who are engaged in advancing geology and the applications of geology from the side of economics. Yet for all that every one of us is well aware that geology is bound up body and soul with the development of the mineral wealth of our land—that mineral wealth by means of which the enterprise of our people has placed our country at the head of the manufacturing and commercial powers of the world. Our science has not only the charge of the working out of all the detailed phenomena, subterranean and superficial, of the great coal fields and iron-ore fields which lie at the foundation of our commercial supremacy as a nation, but it works out the characters and fixes the places of all the stony materials of which our cities and towns are built, our humblest dwellings are constructed, and all our roads and railways are made. It deals with the sources and the quantities and characters of our water supplies, whether deep seated or superficial, the nature and distribution of our soils, and indeed with everything which we derive directly from the ground upon which we tread. Thus a knowledge of the principles and applications of geology is indispensable to the education of the miner, the mine owner, the prospector, the land agent, the land owner, the agriculturist, the civil engineer, and the military engineer.

GEOLOGY AND MAN.

It is as true now as it was in the days when Werner first drew his far-reaching inferences before his charmed listeners that in the characteristic phenomena and varying distribution of the grand mineral masses of the rock formations almost all that concerns the relative habitability of a land depends. Where the hard, intractable rock formations rise boldly out we have our mountain regions—our uplands and highlands—wild areas of pasture and scanty populations, it is true, but the lands of refuge and of freedom in the past and of health and holiday in the present. Where the soft, easily weathered rock formations spread out in gentle slopes or broad undulations we have the wide

plains of our great agricultural districts—the lands, it may be, of peace and plenty, but where life is so easy-going and so monotonous that there is little incentive or opportunity to vary the established order of things, and the local country life remains much the same generation after generation. Between these two extremes lie the areas floored by the gently inclined rocks of our great coal fields, the theaters of an incessant and fierce industrial struggle—a struggle that has its reflection and its effects in the restless energy and the determined advance of their inhabitants.

What well-read geologist among us is not aware that every variation in the contour of our country, as it rises from the encircling seas that have guarded our freedom, is dependent upon its geology? Where the hard rock formations reach the seaboard, project the bold headland and its cliffs. Where the soft rocks come down to the shore line, open out the broad bays. Where the highly resistant rocks are lifted up in broad mass and face the wild ocean, we find a shore land of rugged cliffs and wild inlets, inhabited only by a few hardy fishermen. Where the easily yielding rocks have been depressed in mass by geological movements, we have the long withdrawing estuary, alive with the ships of commerce moving to and fro from the busy and populous seaport at its head.

Or, turning inland and looking over the general aspect of the country, we recognize everywhere not only the paramount influence of the geological formations and geological conditions on the scenery and the relief of the land, but we trace everywhere the persistent effects of these conditions upon the past and present of the people. All the activities of struggling humanity, in the contest for the bare necessities of existence, for mutual protection, for trade and for progress have been limited and controlled by the natural bounds marked out by the unvarying geological factors. The original sites of almost every city and town, village and hamlet, ancient castle and modern mansion were all determined practically by geological considerations. The sites of the old fortresses were fixed by the places of the more or less inaccessible cliffs and scarps, the position of the villages and hamlets by the abundance of the springs, and the settlement of the lands by the comparative richness of the soils. All down the long stream of history the successive waves of invasion, the ebb and flow of conquering armies, the tracks of inland trade and communication, from the time of the Roman ways, through the roads of the middle ages and later, down to the main threads of the network of railways of the present day, have all more or less followed the same general courses, courses determined by the geographical phenomena consequent upon the geological structure of the land.

It is idle to pursue these matters further or recall how all the variations in scenery and scenic beauty are dependent upon geological

causes, or how these causes determine the productiveness or the healthfulness of a district. But it is impossible for us, to whom these matters are as familiar as household words, to conceive that the education of the geographer, the traveler, the man of commerce, the student of hygiene, the artist, the archæologist, the historian, or even the politician can possibly pretend to completeness unless that education has shown him something of the wealth of facts and ideas that flow even from an elementary acquaintance with a knowledge of these things.

Here perhaps we may call to mind the fact that what gives character and especial color to the science of geology is that it is the exponent of the idea of continuous evolution. I had almost said the discoverer; for "he discovers who proves." Its widest conclusions are based upon the assumption and proof of the efficacy of small causes to bring about the greatest cumulative effects. There is probably no educational gymnastic more captivating and invigorating than to work out and fully appreciate the quietly cumulative effects of present natural causes the sea waves gnawing away the shore, the slow sinking of mud layer by layer on the sea floor, the quiet burying up of organisms; next to trace these phenomena backward stage by stage through the rock formations that mark the eons of the past, down to the very base of the geological scale; and, thence returning, to climb back step by step up the long ladder of life, and note the successive incoming of the ascending types of the animate creation, rising higher and higher yet in the scale of being to the crown of all—man himself—"the heir of all the ages."

The discoveries which geology, in company with archæology and anthropology, has made in aid of the solution of the great problem of the antiquity of man are so revolutionary and so recent that they are practically familiar to all.

To one who has gone through a geological training and appreciated its meaning the idea of slow and continuous evolution becomes, as it were, part and parcel of his mental constitution. He naturally carries the same geological methods into the study of humanity in general—always from the developmental point of view, always on the watch for those simple natural causes that may have been capable of bringing about the present known effects, and always in the hope of discovering a slow and natural evolution. It is in this way that he studies the races of mankind, the growth and relations of languages, the forms and distributions of beliefs, the trends of political practice and opinion, the origin and expansion of commerce. He is watching and indeed, as it were, assisting in the development of a living thing growing up before his mental eyes. His interest is excited, his curiosity piqued, and his emotions stirred; and while his imagination is allowed full play, it is always safely confined within the logical bounds of induction, deduction, and verification.

Surely some kind of knowledge and training of this kind is much to be desired for the ordinary man of education and leisure, the literary man, the arts man, the mathematician. Only by some means of this kind does it seem possible to restore the loss of balance due to the self-absorptive and introspective tendency of much of the so-called culture of the present day. Only by some means of this kind can one attain to the needed breadth of outlook and freedom of opinion as respects all that concerns the relation of man and nature.

III.—Geology and Education.

We have seen that a knowledge of geology is indispensable to the complete education of the miner, the prospector, the civil engineer, and the military engineer, and that a first-hand acquaintance with at least its elements is eminently desirable for the agriculturist, the geographer, the traveler, and the biologist. Many may even be willing to admit that the literary man and the man of culture would be the better for knowing something of its principles and its conclusions. But as geologists it is our bounden duty to go much further than this, and urge upon the educationalists of the day the necessity of affording the rising generation such a full opportunity of instruction in that kind of knowledge, of which geology is the keystone, as shall enable our youth to understand and appreciate the more important phenomena of the world at large and the bearing of these upon their own life and surroundings.

Nothing, however, is further from my intention than to suggest that all the youth of the country shall be instructed in the science of geology as such or that geology shall be introduced as a special subject of education except into the higher classes of schools, colleges, and universities. But what I have in my mind is that geology is the center of that group of knowledges which are sometimes collectively referred to as "nature knowledge" and their study as "nature study." The more advanced educationalists have long since suggested and even strongly advocated instruction in nature study for all our youth; but, alas, they are not yet agreed as to what "nature study" shall include or how it shall be taught. At the one extreme are those who apparently would embrace within it instruction in and explanation of all such concrete facts and phenomena as can be brought before the notice of the youthful pupil so as to direct his attention to external nature in general. At the other extreme are those to whom this dwelling upon facts and phenomena appears to be repugnant, if we may judge from the following extract, which I take from a recently published book catalogue: "To those who are striving to make nature study more vital and attractive by revealing a vast realm of nature outside the realm of science and a world of ideas above and beyond the world of facts the

pages following, giving the titles of books dealing with nature and nature studies, are dedicated." As geologists, however, we should presume, I take it, that education in nature study is, in the words of Huxley, "education in that diligent, patient, loving study of all the aspects of nature the results of which constitute exact knowledge or science."

EDUCATION IN EARTH KNOWLEDGE.

However that may be, this at all events is clear: The branch of nature knowledge with which geology and geologists have to do is that which Huxley terms "erdkunde, or earth knowledge, or geology in its etymological sense." So impressed was Huxley with the general need for instruction in this kind of earth knowledge that he practically founded for its study the educational subject which he named "physiography." Yet physiography has come to embrace much that truly belongs to astronomy; and, indeed, a very large proportion of the subject of physiography, as taught in many schools and colleges in Britain at the present day, is essentially astronomical. But here we have to bear in mind that of the two great divisions of nature that of the outside universe which is proper to astronomy concerns individual men but indirectly. The other half of nature, if we may call it so—the world upon which we live and amidst whose phenomena we move and have our being—is always with us and around us, and its conscious systematic study, which we call "earth knowledge," is, in truth, only a methodizing and an extension of the unconscious and unsystematic study that we call "experience," which we are always making from the earliest dawn of our consciousness to the final darkness of old age. This is the kind of nature knowledge—namely, earth knowledge proper, or, in other words, "geonomy" as contrasted with "astronomy"—of which our youth has the greatest need, and it is instruction in this which it is one of the missions of geology to claim for the rising generation.

The day has not yet arrived when it will be possible to define precisely what should be taught under the head of this earth knowledge. But what I would understand by it is that it should embrace instruction which would direct the attention of the scholar not only to the natural phenomena of the world at large, but also to those particular phenomena of the world immediately around him. In its general interpretation its central plane would be the surface of the earth, and from this it would pass upward by proper stages to consider the distribution of all the phenomena, organic and inorganic, above that surface; outward to the study of the meaning and interaction of these phenomena; downward to the study of their history, and onward to the study of their evolution.

The teaching of this earth knowledge could begin in the elementary classes of schools, be continued in rising grades through the higher

classes, and thence extended to the universities. Speaking theoretically, in its earliest stages it should be as simple as possible and cover the ground which is familiar to daily experience or which is fundamental to several of the natural sciences. In its higher stages it should become more specialized and include the facts and principles common to the special group of sciences which will become of value to the scholar in his later studies or in his after life. In the university it might finally be restricted to the perfect knowledge of that one science which the scholar has selected for his specialty and as much of the fellow sciences as has an intimate bearing upon the science which he selects as his own. At every stage a broad foundation should be laid for the superstructure to be erected in the next stage of advance.

But, speaking practically, it is impossible at the present day to lay down any general rules as to the order in which the subjects dealt with under the head of geonomy should be taken up or as to the way in which those subjects should be individually treated. For while it is quite true that the aim should be to instruct in those generalities which are common to many or all of the sciences, we should most strictly guard ourselves from falling into the error implied by many of the text-book writers on physiography, who start with an opening chapter on matter, energy, gravity, and the like—generalities in their essence as yet hardly capable of conception even by the highest intellects. And while it is quite true that the most vivid and lasting means of education is by experiments and deductions carried out by the pupil himself, we should as carefully avoid the equally fatal error of imagining that instruction in a single experimental science, such as chemistry and physics, can do more for the pupil than give him a glimpse of a corner of nature.

It is sometimes suggested that instruction in earth knowledge should commence with the simplest facts and deductions and lead up, stage by stage, to the highest philosophical conceptions and generalizations. But this is not the way in which any branch of knowledge has grown and developed in the past. The human mind is so constituted that it can often appreciate the broadest generalizations in some directions before it can interest itself in the most elementary facts and draw the simplest conclusions in others. What must be done is to ascertain from the study of the several branches of knowledge how they have individually grown during their developmental history in past ages, note the order of subjects which were earliest and most easily appreciated by the human intellect, and give the successive phases of education as nearly as may be in that order.

Again, it is sometimes hinted that the only fruitful education is that which is purely experimental, the deductions and generalizations in which shall be worked out by the scholar himself; and also that all knowledge which is imparted by the didactic method is not true knowledge and is comparatively infertile. But I firmly hold that

both methods are correct, each for itself, and should both be utilized. There are unquestionably some things which are best taught by experiment, and by that demonstration in which the pupil takes the whole or the largest share. But, on the other hand, the facts of science are so overwhelming in number, and some of its grandest conclusions are so dependent on the highest extremes of knowledge, that they must be communicated didactically and must be accepted by the scholar more or less as an article of faith. Indeed, the younger the scholar and the less his experience, the more certain is he to accept as unquestionable truths the assertions of his instructors. It would be the height of folly to neglect the advantages of all this side of a youth's education in those years of his life when he is most qualified to profit by it.

The fact is that in the imparting of earth knowledge, as in any other kind of instruction, both educational methods—didactic and experimental, authoritative and original—should be utilized together. It is a matter for the educationalist to find out what sections of a subject and what stages of a subject are best imparted by one method and what by another. The only rule which can be laid down is that the didactic and authoritative method is certain to have less and less effect as the scholar grows older and his experience broadens, and the experimental and original more and more. But there is no escape from the conclusion that it is the common interest of the teacher and the scholar to make use of both methods; for the knowledge of every man—the genius, the scholar, the wise man, and the fool—is alike in this, that it is the sum of that knowledge which is due to his own individual experience and that portion of the collective knowledge of humanity which is due to the antecedent experiences of his forefathers and which he has received at second hand. It is not that the present educational systems are wrong in laying stress on the memorizing and the applying of what is already known, but that they are defective in neglecting the individual and original half of a liberal education.

As I have already pointed out, the central plane of geonomy is the knowledge of the surface of the earth, whose present conditions belong to geography, and whose past and evolution belong to geology. But in the earlier phases of the education of the scholar there can and need be no distinction in his mind between these two sciences; they are rather combined in a geonomic stage—in a generalized organism, so to speak—destined to evolve and differentiate later on. Yet in this early stage the dominating section of the subject is essentially geography. As such it presents two very different aspects—the general geography, namely, that of the world and its surface as a whole; and the local geography, namely, the geography of the home and the surroundings of the scholar. The general geography must be taught di-

dactically, with the aid of such lecture illustrations as globes and maps; and the instruction must be received by the scholar more or less as an article of faith. The local geography, however—and by this I would understand not only the topography of the district, but the geography of the town or village, the playground, and the very schoolroom itself—should be taught practically at first hand, the data being recognized, collected, and classified, the experiments made, and the conclusions drawn, as much as possible by the scholar himself.

MAPS AS MEANS AND SYMBOLS OF EARTH KNOWLEDGE.

It is along this local side of geonomy that some of the most important advantages will accrue to geology, and not only to geology but to all its associated sciences. One of the most necessary qualifications for the geologist and the geographer, and indeed for all students of those sciences and arts in which facts and phenomena have to be arranged in their order of distribution, is a familiarity with the use of maps and a knowledge of how they are constructed. But one of the commonest results of the present modes of giving instruction in maps and map making in most schools is to cause this kind of knowledge to become distasteful to the learner. And the consequence is that for one fairly well educated man who can read a good map of his own native district, there are hundreds to whom this is impossible. A detailed topographical map or a geological map is practically a mystery to the average man, and yet the training which would have enabled him to appreciate and enjoy them both might, if given properly in his early years, have afforded him many a pleasant and interesting break in the monotony of his ordinary school work. He has doubtless been shown in his geographical classes the ordinary maps of the world, and those of the continents and his own country; he has perhaps copied some of them laboriously in manuscript and very probably passed examinations in drawing them from memory. But they were always more or less dead things to him, because they dealt with lands and districts which he had never beheld and not with the familiar objects of the school and the home. He has never seen them grow up before his own eyes, built up from facts collected by himself and his fellows.

We should like to see the lower classes of all schools making a map of their own schoolroom and playground. We should like to see the scholars at a higher stage studying and exercised in the large scale 25-inch map of the locality, with the school in the center; those at a higher stage engaged on the 6-inch map of the neighborhood, and so on. Stage by stage the scholars might pass to the study of the 1-inch map of the district or county. Then, when once these maps had become familiar objects, the learners should be taken out on occasional excursions into the country with the maps in their hands, and educated in some of the higher grades of that earth knowledge which can

only be seen and appreciated in the open air. Later on the scholars might pass to the study of natural agencies, the origin and meaning of landscape, to geology proper, and thence to the study of the intimate relations of nature and man.

But it must be acknowledged that the present lack of this kind of instruction is not to be wholly ascribed to the teachers. Good local maps were until recently practically nonexistent. The Government ordnance and geological surveys have now made these at great national expense, but so hidden away are they that few except military and civil engineers and surveyors use them freely, and very few have recognized their perfection and importance. Now, that these maps are becoming completed, we are beginning to discover that they constitute a most important educational engine. They are still, however, sold at too high a price. When we bear in mind the important fact that each member of a class should be provided with a fresh map at every successive stage, the cost to parents and school managers of this branch of geonomic training, as matters stand, would be considerable. Yet we may be sure that this kind of instruction is certain to come about. It becomes, therefore, a serious question whether the Government departments concerned with the surveying of our country could not be authorized to supply these maps to school classes, either as part of the local Government grant or at a very cheap rate. The actual surveying of the country and the preparation of the maps already costs several thousands of pounds annually, which are ungrudgingly paid by the nation. Surely an extra yearly grant of a few scores of pounds to enable the Government map-making departments to supply these maps to schools at a nominal price would be so trivial, whether compared on the one hand with the large grant already made for the original production of these maps or on the other hand with their educational value to the rising generation, that it would undoubtedly be welcomed by all.

And once our people became aware of the excellence of these national maps, topographical and geological, the demand for them, which is comparatively small at present, would certainly grow. As yet, however, the public are hardly aware even of their existence. A great advance has been made of late by hanging up selected, but unfortunately not local, portions of these maps in post-offices, with a notice that the maps can be obtained from the local agent. But what are really wanted in all post-offices are framed copies of the 1-inch and 6-inch maps of the locality, hung up so as to be available for reference by all comers, and a copy of each of these and the other local maps kept in stock, together with a simple catalogue of all the national maps and memoirs, any one of which should be obtainable by return of post. The post-offices are, in the very nature of things, the best advertising places in the country, and they are in direct touch with

the map-issuing departments of the Government. Once the people become accustomed by means of their school teaching, and by constant sight of these maps in the post-offices to regard them as a factor in their daily life, that which is now a luxury for the learned and the few will become more or less a necessity for the general and the many, and they will demand for themselves and their children a more intimate acquaintance with that earth knowledge of which these maps are a symbol a consummation in which the science of geology will benefit by no means last and by no means least.

CONCLUSION.

But to what extent instruction in that earth knowledge of which geology is the soul and center will constitute an integral portion of the general education during the present century must depend in part on the efforts of geologists and in part on the enlightenment and emancipation of the educationalists themselves. As geologists, however, we have the assurance, justified by unbroken tradition, that our views will eventually be accepted simply because they are inevitable.

In the direction of practice also we may look forward with equal confidence, especially to the spread of geological facts and principles and to the extension of the applications of our science. The enormous increase in the utilization of the mineral resources of our country which is now going on, and the rapid opening up of the many mineral districts throughout the world-wide possessions of the Empire, bring day by day a larger array of students to our science from the side of economics.

And turning to the side of research we are all of us aware that some of the grandest and most difficult problems of our science still await solution—problems as attractive, as stimulating, and as rich in promise as were any of those of the past. And if that past be a true index of the future we may be well satisfied that there is no science which need outstrip ours in its rate of progress. When we call to mind that at the commencement of the great French Revolution, whose echoes have as yet hardly died away, our science was just struggling into existence, and that in the short time which has since elapsed it has placed itself abreast of the foremost, we have every incentive to push forward and to emulate those great pioneers in the science, in the mighty sum of whose conquests we rejoice and take a pardonable pride.

We have indeed abundant cause for pride, yet none for vainglory. No science, it is true, has made so swift an advance as geology, but certainly to none has ever been afforded so magnificent an opportunity. The veil of ignorance and of traditional opinion which hid from the men of the Middle Ages the wonders which geology has since revealed was so dark and opaque that until the close of the eighteenth century no

light could penetrate beyond. But so old and flimsy was it that when once the strong hand of the geologist had torn it, it was soon rent through from top to bottom, and in the flood of light which entered what wonder that discovery followed discovery in almost endless succession.

And we have deep cause for thankfulness in that these discoveries have been of benefit not for our science alone, but for all its fellow-sciences; and more, that they have been from the first of supreme importance to man himself, his industries, and his progress, and to the study of his history, his origin, and indeed of all that binds him and his fellow-creatures to the world on which he lives.

While, therefore, we move on confidently together in this dawn of a new era, blazing forward the straight and narrow trail of research marked out up to this point by our geological forefathers—"the old trail, the lone trail, the trail that's always new"—let us ever remember that our science is not only the interpreter of nature, but also the servant of humanity.

TERRESTRIAL MAGNETISM IN ITS RELATION TO GEOGRAPHY.[a]

By Capt. Ettrick W. Creak, C. B., R. N., F. R. S.

Of the six distinguished naval officers who have previously presided over this section, four were arctic explorers; and therefore, possessing personal experience in arctic regions, they naturally gave prominence to the deeply interesting subject of the past and future of arctic discovery in their addresses, while not forgetting other matters relating to the geography of the sea. The remaining officers, from their immediate connection with all that relates to the physical condition of the ocean, in its widest sense, coupled with the great importance of giving the fruits of their knowledge to the world, took that subject as their principal theme.

Valuable as are contributions to our knowledge of the physics of the ocean to the world in general, and especially to the mariner and waterborne landsman, I propose to take a different course, and bring to your notice the subject of terrestrial magnetism in its relation to geography. In doing so I shall endeavor to show that much may be done by the traveler on land and the seaman at sea in helping to fathom the mysteries connected with the behavior of the freely suspended magnetic needle as it is carried about over that great magnet, the earth, by observations in different regions, and even in limited areas.

I would, however, pause a moment to call attention to the presence of several distinguished meteorologists at this meeting, who will surely attract many to the consideration of matters connected with the important science of meteorology, which already occupies considerable attention from travelers. I feel sure, therefore, that geographers will be glad to accord a hearty welcome to the members of the International Meteorological Congress now assembled in this town, and especially to the foreign visitors who honor us by their presence.

Some one may ask, What has terrestrial magnetism to do with geography? I reply, Excellent lectures on that subject of growing importance have been given under the direct auspices of the Royal

[a] The president's address to Section E (geography) at the Southport meeting of the British Association. Reprinted after revision by the author from the Scottish Geographical Magazine for October, 1903.

Geographical Society; one in 1878 by the late Capt. Sir Frederick Evans, and another in 1897 by Sir Arthur Rücker. And I would here quote the opinion of Doctor Mill, when defining geography, in my support: "Geography is the science which deals with the forms of the earth's crust and with the influence which these forms exercise on the distribution of other phenomena."

We know now that the normal distribution of the earth's magnetism for any epoch is in many localities seriously affected according as the nature of the country surveyed be mountainous, or generally a plain, in the form of islands (or mountains standing out of the sea), and from land under the sea. There is also reason to suspect that the magnetism of that portion of the earth covered by the oceans differs in intensity from that of the dry land we inhabit. A connection between the disturbances of the earth's crust in earthquakes and disturbances of the magnetic needle also seems to exist, although the evidence on this point is not conclusive.

MAGNETIC SURVEYS.

Previously to the year 1880 there were two periods of exceptional activity on the part of contributors to our knowledge of the earth's magnetism, during which the scientific sailor in his ship on the trackless ocean combined with his brethren on land in making a magnetic survey of the globe.

The first period was that of 1843–1849, during which not only were fixed observatories established at Toronto, Saint Helena, Capetown, and Hobart for hourly observations of the movements of the magnetic needle, but to use Sabine's words, "that great national undertaking, the magnetic survey of the south polar regions of the globe," the forerunner of our present antarctic expedition, was accomplished by Ross and his companions almost entirely at sea.

This antarctic survey was carried out during the years 1840–1845, and the results given to the world as soon as possible by Sabine. The results afterwards formed a valuable contribution when constructing his maps of equal lines of magnetic declination, inclination, and intensity for the whole world, a great work for the completion of which Sabine employed every available observation made up to the year 1870, whether on land or at sea.

Readers of these contributions can not fail to be struck with the great number of observations made by such travelers as Hansteen and Due, Erman and Wrangel, extending from western Europe to far into Siberia.

The second period was that of 1870–1880, during which not only was there much activity among observers on land, but that expedition, so fruitful to science, the voyage of H. M. S. *Challenger*, took place. During the years 1872–1876 we find the sailor in the *Challenger* doing most valuable work in carrying out a magnetic survey of certain por-

tions of the great oceans, valuble not only for needful uses in making charts for the seaman, but also as a contribution to magnetic science.

Prior to this expedition very little was known from observation of the distribution of terrestrial magnetism in the central regions of the north and south Pacific oceans, and Sabine's charts are consequently defective there.

Combining the *Challenger* magnetical results with those of all available observations made by others of Her Majesty's ships and by colonial and foreign governments, I was enabled to compile the charts of the magnetic elements for the epoch of 1880, which were published in the report of the scientific results of H. M. S. *Challenger*. I will venture to say that these charts give a fairly accurate representation of the normal distribution of the earth's magnetism between parallels of 70° north and 40° south. Beyond these limits, either northward or southward, there is a degree of uncertainty about the value of the lines of equal value, especially in the southern regions—an uncertainty which we have reason to hope will be dissipated when we know the full results obtained by Captain Scott and the gallant band he commands, for as yet we have to be content with some eddies of the full tide of his success.

Until the *Discovery* was built the *Challenger* was the last vessel specially selected with a view to obtaining magnetic observations at sea, so that for several years past results obtained on land have been our mainstay. Thus, elaborate magnetic surveys with fruitful results have been carried out in recent years in the British Isles by Rücker and Thorpe. France, Germany, Holland, and some smaller districts in Europe have also been carefully surveyed, and British India partially so, by Messrs. Schlagintweit in 1857–58. The latter country is being again magnetically surveyed under the auspices of the Indian government.

On the American continent the coast and geodetic survey of the vast territories comprised in the United States, which has been so many years in progress, has been accompanied by an extended magnetic survey during the last fifty-two years, which is now under the able direction of Dr. L. A. Bauer. Resulting from this some excellent charts of the magnetic declination in the United States have been published from time to time, and the last, for the epoch 1902, is based upon 8,000 observations.

There are other contributions to terrestrial magnetism for positions on various coasts from the surveying service of the royal navy, and our ships of war are constantly assisting with their quota to the magnetic declination, or variation, as sailors prefer to call it; and wisely so, I trow, for have they not the declination of the sun and other heavenly bodies constantly in use in the computation of their ship's position?

This work of the royal navy and the Indian marine is one of great importance, both in the interests of practical navigation and of science; for besides the equipment of instruments for absolute determinations of the declination, dip, and horizontal force supplied to certain of our surveying ships, every seagoing vessel in the service carries a landing compass, specially tested, by means of which the declination can be observed with considerable accuracy on land.

Although observers of many other objects may still speak of their "heritage, the sea," as a mine of wealth waiting for them to explore, unfortunately for magnetic observations, we can no longer say "the hollow oak our palace is," for wood has been everywhere replaced by iron or steel in our ships, to the destruction of accurate observations of dip and force on board of them. Experience, however, has shown that very useful results, as regards the declination, can be obtained every time a ship is "swung," either for that purpose alone or in the ordinary course of ascertaining the errors of the compass due to the iron or steel of the ship.

As an example of this method, the cruise of the training squadron to Spitzbergen and Norway in 1895 may be cited, when several most useful observations were made at sea in regions but seldom visited. Again, only this year a squadron of our ships cruising together near Madagascar separated to a distance of a mile apart and "swung" to ascertain the declination.

I would here note that all the magnetic observations made by the officers of Her Majesty's ships during the years 1890–1900 have been published in a convenient form by the hydrographic department of the Admiralty.

The fact remains, however, that a great portion of the world, other than the coasts, continues unknown to the searching action of the magnetic needle, while the two-thirds of the globe covered by water is still worse off. Among other regions I would specify Africa, which, apart from the coasts, Cape Colony, and the Nile valley to latitude $5\frac{1}{2}°$ north, is absolutely a new field for the observer.

Moreover, the elaborate surveys I have mentioned show how much the results depend upon the nature of the locality. I am therefore convinced that travelers on land, provided with a proper equipment of instruments for conducting a land survey of the strange countries which they may visit, and mapping the same correctly, can, with a small addition to the weight they have to carry, make a valuable contribution to our knowledge of terrestrial magnetism, commencing with observations at their principal stations and filling in the intermediate space with as many others as circumstances will permit.

THE ANTARCTIC EXPEDITION.

Of the magnetic work of our antarctic expedition we know that since the *Discovery* entered the pack—and, as far as terrestrial magnetism is concerned, upon the most important part of that work—every opportunity has been seized for making observations.

Lyttelton, New Zealand (where there is now a regular fixed magnetic observatory), was made the primary southern base station of the expedition; the winter quarters of the *Discovery*, the secondary southern base station. Before settling down in winter quarters, magnetic observations were made on board the ship during the cruise to and from the most easterly position attained off King Edward VII Land in latitude 76° south, longitude 152½° west, and she was successfully swung off Cape Crozier to ascertain the disturbing effects of the iron upon the compasses and dip and force instruments mounted in the ship's observatory.

As a ship fitted to meet the most stormy seas and to buffet with the ice, the *Discovery* has been a great success. Let me add another tribute to her value. From Spithead until she reached New Zealand but small corrections were required for reducing the observations made on board. The experience of Ross's Antarctic expedition had, however, taught the lesson that two wood-built ships, the *Erebus* and *Terror*, with but some 3 to 4 degrees of deviation of the compass at Simons Bay, South Africa, found as much as 56 degrees of deviation at their position farthest south, an amount almost prohibitory of good results being obtained on board.

How fared the *Discovery?* I have been told by Lieutenant Shackleton—for whose return to England on account of his health we must all feel great sympathy—that a maximum of only 11 degrees of deviation was observed at her most southerly position. From this we may look forward hopefully to magnetic results of a value hitherto unattained in those regions.

At winter quarters, besides the monthly absolute observations of the magnetic elements, the Eschenhagen variometers or self-registering instruments for continuously recording the changes in the declination, horizontal force, and vertical force were established, and in good working order at the time appointed for commencing the year's observations.

I may here remind you that some time previously to the departure of the British and German Antarctic expeditions a scheme of cooperation had been established between them, according to which observations of exactly the same nature, with the same form of variometers, were to be carried out at their respective winter quarters during a whole year, commencing March 1, 1902. Besides the continuous observations with the variometers, regular term days and term hours

were agreed upon for obtaining special observations with them at the same moment of Greenwich mean time. Both expeditions have successfully completed this part of their intended work.

To cooperate in like manner with these far southern stations, the Argentine Government sent a special party of observers to Staten Island, near Cape Horn, and the Germans another to Kerguelen Land, whilst New Zealand entered heartily into the work. In additon, similar observations were arranged to be made in certain British and colonial observatories, which include Kew, Falmouth, Bombay, Mauritius, and Melbourne; also in German and other foreign observatories.

We have all read thrilling accounts of the journeys of the several traveling parties which set out from the *Discovery*, and of the imminent dangers to life they encountered and how they happily escaped them except one brave fellow named Vince, who disappeared over one of those mighty ice cliffs, upon which all Antarctic voyagers descant, into the sea. In spite of all this there is a record of magnetic observations taken on these journeys of which only an outline has yet been given. Anticipations of the value of these observations are somewhat clouded when we read in one report that hills "more inland were composed of granite rock, split and broken, as well as weatherworn, into extraordinary shapes. The lower or more outer hills consisted of quartz, etc., with basaltic dikes cutting through them." Consequently, we have to fear the effects of local magnetic disturbances of the needle in the land observations, while buoyed up with the hope of obtaining normal results on board the ship.

Judging from some land observations which have been received it appears that considerable changes have taken place in the values of the magnetic elements in the regions we are considering, but when making comparisons we have to remember the sixty years which have elapsed since Ross's time, and that he had nothing like the advantage of steam for his ships, or of instruments of precision like our present ship *Discovery*. His ships also were, as we have already remarked, much worse magnetically, causing far more serious disturbance of the instruments. Hence the changes we note may not be entirely due to changes in the earth's magnetism.

The observations made by the officers of the *Southern Cross* at Cape Adare in 1899–1900 also contribute to this question of magnetic change.

THE MAGNETIC POLES OF THE EARTH.

I will now refer to those two areas on the globe where the dipping needle stands vertically, known as the magnetic poles. The determination of the exact position of these areas is of great importance to magnetic science, and I will just glance at what is being done to solve the problem.

Let us consider the North Pole first, the approximate position of which we know best from observation. If one were asked to say exactly where that pole has been in observation times, whether it has moved, or where it now is, the answer must be, "I do not know." It is true that Ross in 1831, by a single observation, considered that he had fixed its position, and I believe hoisted the British flag over the spot, taking possession thereof; but he may or may not have set up his dip circle over a position affected by serious magnetic disturbance, and therefore we must still be doubtful of his complete success from a magnetic point of view. Although eminent mathematicians have calculated its position, and Neumayer in 1885 gave a place to it on his charts of that year, we have still to wait for observation to settle the question, for one epoch at least.

Happily, I am able to repeat the good news that the *Norwegian*, Capt. Roald Amundsen, sailed in June last with the express object of making a magnetic survey of Ross's position and of the surrounding regions, in order to fix the position of the north magnetic pole. Furnished with suitable instruments of the latest pattern, he proposes to continue his investigations until 1905, when we may look for his return and the fulfillment of our hopes.

As far as we can now see, the south magnetic pole can not be approached very nearly by the traveler, and we can only lay siege to it by observing at stations some distance off, but encircling it. We have our own expedition on one side of it, and now with the return of the *Gauss* to South Africa in June last we have learned that that vessel wintered in latitude 66° 2′ south, longitude 89° 48′ east, a position on the opposite side of the supposed site of the magnetic pole to that of the *Discovery*. We may now pause to record our warm congratulations to Doctor von Drygalski and his companions on their safe return, accompanied by the welcome report that their expedition has proved successful.

In addition to the British and German expeditions, there are the Swedish expedition and the Scottish expedition. Therefore, with so many nationalities working in widely different localities surrounding it, we have every reason to expect that the position of the south magnetic pole will be determined.

THE SECULAR CHANGE.

When, in the year 1600, Gilbert announced to the world that the earth is a great magnet, he believed it to be a stable magnet; and it was left to Gellibrand, some thirty-four years later, by his discovery of the annual change of the magnetic declination near London, to show that this could hardly be the case. Ever since then the remarkable and unceasing changes in the magnetism of the earth have been the subject of constant observation by magneticians and of investigation by some

of the ablest philosophers in Europe and America. Year after year new data are amassed as to the changes going on in the distribution of the magnetism of the earth, but as yet we have been favored by hypotheses only as to the causes of the wondrous changes which the magnetic needle records.

These hypotheses were at one time chiefly based upon a consideration of the secular change in the declination, but it is now certain that we must take into account the whole phenomena connected with the movements of the needle if we are to arrive at any satisfactory result. Besides, it will not suffice to take our data solely from existing fixed observatories, however relatively well placed and equipped, and valuable as they certainly are, for it now appears that the secular change is partly dependent upon locality, and that even at places not many miles apart differences in results unaccounted for by distance have been obtained.

The tendency of observation is increasingly to show that the secular change of the magnetic elements is not a world-wide progress of the magnetic needle moving regularly in certain directions, as if solely caused by the regular rotation during a long series of years of the magnetic poles round the geographical poles, for if you examine Map No. 1,[a] showing the results of observations during the years 1840–1880, as regards secular change, you will observe that there are local causes at work in certain regions, whilst in others there is rest, which must largely modify the effect of any polar rotation.

Allow me to explain further. The plain lines on Map No. 1 indicate approximate regions of no secular change in the declination, and the small arrows the general direction (not the amount) in which the north-seeking end of the horizontal needle was moving during those forty years. The foci of greatest change in the declination, with the approximate amount of annual change in the Northern Hemisphere, are shown in the German Ocean and northwestern Alaska, in the Southern Hemisphere off the coast of Brazil, and in the South Pacific between New Zealand and Cape Horn. The two foci of greatest annual change in the dip are shown—one in the Gulf of Guinea, where the north-seeking end of the needle was being repelled strongly upward; the other on the west side of Tierra del Fuego, where the north-seeking end of the needle was being attracted strongly downward.

It is remarkable that the lines of no change in the declination pass through the foci of greatest change in the dip. If the needle be repelled upward, as at the Gulf of Guinea focus, it will be found to be moving to the eastward on the east side of the whole line of no change in the declination from the Cape of Good Hope to Labrador; to the westward, on the west side. If the needle be attracted downward, as at the Tierra

[a] Originally prepared by the author for the "Magnetical Results," H. M. S. *Challenger*.

del Fuego focus, it will be found moving to the westward on the east side of the whole line of no declination from that focus to near Vancouver Island; to the eastward on the west side.

A similar result may be seen in the line passing through a minor focus of the dip near Hongkong.

Judging from analogy, there should be another focus of change in the dip in latitude 70° north, longitude 115° east, or about the position assigned to the Siberian focus of greatest force.[a]

On Map No. 2 are shown lines of equal value of the declination—the red lines for the year 1880, the black lines for the year 1895. From these, when shown on a large scale, we may deduce the mean annual change which has taken place in the declination during the fifteen years elapsed.

In this map we are reminded of the different results we obtain in different localities; for if a line be drawn from Wellington, in New Zealand, past Cape York, in Australia, to Hongkong, little or no change will be found in the neighboring region since 1840. Again, the line of no change in the declination shown on Map No. 1, to be following much the same direction as the great mountain ranges on the west side of the American Continent, has hardly moved for many years, according to the observations available.

On the other hand, let us now turn to an example of the remarkable changes which may take place in the declination unexpectedly and locally. The island of Zanzibar and the east coast of Africa were constantly being visited by our surveying ships and ships of war up to the year 1880, observations of the declination being made every year at Zanzibar during the epoch 1870–1880. The results showed that from Cape Town nearly to Cape Guardafui the annual change of that element hardly exceeded 1′.

During the succeeding years of 1890–91 observations were made by the Germans at Dar-es-Salaam and some other places on the neighboring coasts, with the result that the declination was found to be changing at first 3 minutes annually, and since that period it had reached 10 to 12 minutes at Dar-es-Salaam. Subsequent observations at the latter place in 1896–1898 confirmed the fact of the great change, and in addition our surveying ship on the station, specially ordered to "swing" at different places in deep water off the coast, generally confirmed the results. It is remarkable that while such great changes should have taken place between Cape Town and Cape Guardafui, Aden and the region about the Straits of Bab el Mandeb seem to be comparatively unaffected.

[a] The results described in the four preceding paragraphs and given in Map No. 1 were also exhibited on a 12-inch globe with the addition of magnetic meridians for the epoch 1880, terminating in the supposed positions of the magnetic poles. This 12-inch globe is now in the South Kensington Museum, London.

LOCAL MAGNETIC DISTURBANCE.

In Map No. 2 normal lines of equal value of the declination are recorded, and as far as the greater part of the globe covered by water is concerned we may accept them as undisturbed values, for we have yet to learn that there are any local magnetic disturbances of the needle in depths beyond 100 fathoms.

When, however, we come to the land, there is an increasing difficulty in finding districts of only a few miles in extent where the observed values of the magnetic elements at different stations therein do not differ more widely than they should if we considered only their relative position on the earth as a magnet. Take Rücker and Thorpe's maps of the British Isles and those of the United States, for example, where the lines of equal value are drawn in accordance with the observations, with the result that they form extraordinary loops and curves differing largely from the normal curves of calculation.

From among numerous examples of disturbance of the declination on land, two may be quoted. In the Rapakivi district, near Wiborg, a Russian surveying officer in the year 1890 observed a disturbance of 180 degrees, or, in other words, the north point of his compass pointed due south. At Invercargill, in New Zealand, within a circle of 30 feet radius a difference of 56 degrees was found. Even on board ships in the same harbor different results are sometimes observed, as our training squadron found at Reikiavik, in Iceland, and notably in our ships at Bermuda.

It is hardly necessary to add that the dip and force are often largely subject to like disturbance, but I do so in order to warn travelers and surveyors that observations in one position often convey but a partial truth; they should be supplemented by as many more as possible in the neighborhood or district. Erroneous values of the secular change have also been published from the various observers not having occupied exactly the same spot, and even varied heights of the instrument from the ground may make a serious difference, as at Rapakivi, before mentioned, and at Madeira, where the officers of the *Challenger* expedition found the dip at a foot above the ground to be 48° 46′ north; at 3¼ feet above the ground, 56° 18′ north, at the same spot.

All mountainous districts are specially open to suspicion of magnetic disturbance, and we know from comparison with normal observations at sea that those mountains standing out of the deep sea, which we call islands, are considerably so affected.

MAGNETIC SHOALS.

The idea that the compasses of ships could be affected by the attraction of the neighboring dry land, causing those ships to be unsuspectingly diverted from their correct course, was long a favorite theory of those who discussed the causes of shipwreck, but it was "a

fond thing vainly invented." I can hardly say this idea is yet exploded, but from what has already been said about local magnetic disturbance on land, it is not a matter of surprise that similar sources of disturbance should exist in the land under the sea, for it has been found that in certain localities, in depths of water sufficient to float the largest ironclad, considerable disturbances are caused in the compasses of ships.

An area of remarkable disturbance having been reported as existing off Cossack, northwestern Australia, H. M. S. *Penguin*, a surveying ship provided with the necessary magnetic instruments, was sent by the Admiralty in 1891 to make a complete magnetic survey of the locality, with a view to ascertaining the facts and placing them on a scientific basis. An area of disturbance 3.5 miles long by 2 miles broad, with not less than 8 fathoms of water over it, was found lying in a northeast by east and southwest by west direction. At one position the disturbing force was sufficient to deflect the *Penguin's* compass 56 degrees; in another—the focus of principal disturbance—the dip on board was increased by 29 degrees, and this at a distance of over 2 miles from the nearest visible land, upon which only a small disturbance of the dip was found.

This remarkable area of disturbance was then called a "magnetic shoal," a term which at first sight hardly appears to be applicable. We have, however, become familiar with the terms "ridge line, valley line, peak, and col," as applied to areas of magnetic disturbance on land; therefore I think we may conveniently designate areas of magnetic disturbance in land under the sea "magnetic shoals."

This year His Majesty's surveying ship *Research* has examined and placed a magnetic shoal in East Loch Roag (island of Lewis), but as all our surveying ships are practically iron ships, it was impossible from observations on board to obtain the exact values of the disturbing forces prevailing in this shoal. The reason for this is that, although we may accurately measure the disturbing forces of the iron of the ship in deep water, directly she is placed over the shoal induction takes place, and we can no longer determine to what extent the observed disturbances are due to the ship's newly developed magnetism, or to what extent the shoal alone produces them.

We can, nevertheless, even in an iron ship, accurately place and show the dimensions of a magnetic shoal and the direction in which a ship's compass will be deflected in any part of it by compass observations only. Is it not, therefore, the duty of any ship meeting with such shoals to stop and fix their position?

The general law governing the distribution of magnetism on these magnetic shoals is that in the Northern Hemisphere the north point of the compass is drawn toward the focus of greatest dip; in the Southern Hemisphere it is repelled. The results at East Loch Roag proved an exception, the north point of the compass being repelled.

TERRESTRIAL MAGNETISM AND GEOLOGY.

I have already referred to the question of local magnetic disturbance as one of great importance in magnetic surveys. The causes of these disturbances were at one time a matter of opinion, but the evidence of the elaborate magnetic surveys I have alluded to, when compared with the geological maps of the same countries, points clearly to magnetic rocks as their chief origin.

Magnetic rocks may be present, but from their peculiar position fail to disturb the needle; on the other hand, as Rücker writes in his summary of the results of the great magnetic survey of the British Isles conducted by Thorpe and himself, "the magnet would be capable of detecting large masses of magnetic rock at a depth of several miles," a distance not yet attained by the science of the geologist.

Again, Doctor Rijckevorsel, in his survey of Holland for the epoch 1891, was convinced that "in some cases, in many, perhaps, there must be a direct relation between geology and terrestrial magnetism, and that many of the magnetic features must be in some way determined by the geological structure of the underground."

During the years 1897–1899 a magnetic survey was made of the Kaiserstuhl, a mountainous district in the neighborhood of Freiburg, in Baden, by Dr. G. Meyer. Exact topographical and geological surveys had been previously made, and the object of the magnetic survey was to show how far the magnetic disturbances of the needle were connected with geological confirmations. Here, again, it was found that the magnetic and geological features of the district showed considerable agreement, basaltic rocks being the origin of the disturbance. This was not all, for in the level country adjacent to the Rhine and near Breisach unsuspected masses of basalt were found by the agency of the magnetic needle.

More recently we find our naval officers in H. M. S. *Penguin*, with a complete outfit of magnetic instruments, making a magnetic survey of Funafuti atoll and assisting the geologist by pointing out, by means of the observed disturbance of the needle, the probable positions in the lagoon in which rock would be most accessible to their boring apparatus.

Leaving the geologist and the magnetician to work in harmony for their common weal, let us turn to some other aspects of the good work already accomplished and to be accomplished by magnetic observers.

MAGNETIC CHARTS.

Of the valuable work of the several fixed magnetic observatories of the world, I may remark that they are constantly recording the never-ceasing movements of the needle, the key to many mysteries to science existing in the world and external to it, but of which we have not yet learned the use. Unfortunately, many of these once fixed observatories

have become travelers to positions where the earth can carry on its work on the needle undisturbed by electric trams and railways which have sprung up near them, and it is to be hoped they will find rest there for many years to come.

Of the 42 observatories which publish the values of the magnetic elements obtained there, 32 are situated northward of the parallel of 30 degrees north, and only 4 in south latitude; and it is a grief to magneticians that so important a position as Cape Town or its neighborhood does not make an additional fixed magnetic observatory of the first order.

Thus, as far as our present question of magnetic charts and their compilation is concerned, the observatories do not contribute largely, but we should be very grateful to them for the accurate observations of the secular change they provide which are so difficult to obtain elsewhere.

Of the value of magnetic charts for different epochs I have much to say, as they are required for purely scientific inquiry as well as for practical uses. It is only by their means that we can really compare the enormous changes which take place in the magnetism of the globe as a whole; they are useful to the miner, but considerably more so to the seaman. Had it not been for the charts compiled from the results of the untiring labors of travelers by land and observers at sea in the field of terrestrial magnetism during the last century, not only would science have been miserably poorer, but it is not too much to say that the modern iron or steel steamship traversing the ocean on the darkest night at great speed would have been almost an impossibility, whereas with their aid the modern navigators can drive their ships at a speed of 26.5 statute miles an hour with comparative confidence, even when neither sun, moon, nor stars are appearing.

Of the large number of travelers by sea, including those who embark with the purpose of increasing our geographical knowledge of distant lands and busying themselves with most useful inquiries into the geology, botany, zoology, and meteorology of the regions they visit, few realize that when they set foot on board ship (for all ships are now constructed of iron or steel) they are living inside a magnet. Truly a magnet, having become one by the inductive action of that great parent magnet—the earth.

How fares the compass on board those magnets, the ships, that instrument so indispensable to navigation, which Victor Hugo has forcibly called "the soul of the ship," and of which it has been written,

> A rusted nail, placed near the faithful compass,
> Will sway it from the truth, and wreck an argosy.

And if so small a thing as an iron nail be a danger, what are we to say to the iron ship? Let us for a moment consider this important matter.

If the nature of the whole of the iron or steel used in construction of ships were such as to become permanently magnetic, their navigation would be much simplified, as our knowledge of terrestrial magnetism would enable us to provide correctors for any disturbing effects of such iron on the compass, which would then point correctly. But ships, taken as a whole, are generally more or less unstable magnets, and constantly subject to change, not only on change of geographical position, but also of direction of the ship's head with regard to the magnetic meridian. Thus, a ship steering on an easterly course may be temporarily magnetized to a certain extent, but on reversing the ship's course to west she would after a time become temporarily magnetized to the same amount but in the opposite direction, the north point of the compass being attracted in each case to that side of the ship which is southernmost.

Shortly, we may define the action of the earth's magnetism on the iron of a ship as follows: The earth being surrounded by a magnetic field of force differing greatly in intensity and direction in the regions from the north pole to the equator and the equator to the south pole, the ship's magnetic condition is largely dependent upon the direction of her head while building and the part of that field she occupied at the time; partly upon her position in the magnetic field she traverses at any given time during a voyage.

For the reasons I have given, magnetic charts are a necessity for practical purposes and in the following order of value: That of the magnetic declination of variation which is constantly in use, especially in such parts of the world as the Saint Lawrence and the approaches to the English Channel, where the declination changes very rapidly as the ship proceeds on her course. Next, that of the dip and force, which are not only immediately useful when correcting the ship's compass, but are required in the analysis of a ship's magnetism both as regards present knowledge and future improvements in placing compasses on board.

If astronomers have for a very long time been able to publish for several years in advance exact data concerning the heavenly bodies, is it too much to hope that magneticians will before long also be able to publish correct magnetic charts to cover several years in advance of any present epoch? If this is to be done within reasonable time, there must be a long pull, a strong pull, and a pull all together of magnetic observers in all lands, and accumulated data must also be discussed.

ON MAGNETIC INSTRUMENTS FOR TRAVELERS.

Travelers in unsurveyed countries, if properly instructed and equipped, can do good service to science by observing the three magnetic elements of declination, inclination or dip, and force at as many stations as circumstances will permit. Hence the following remarks:

For the purpose of making the most exact magnetic survey the best equipment of instruments consists of the well-known unifilar magnetometer, with fittings for observing the declination, and a Barrow dip circle. To some travelers these instruments might be found too bulky, and in some regions too delicate, as well as heavy to carry.

Of suitable instruments made abroad, those used by M. Moureaux in his survey of France may be mentioned, as they are of similar type, but much smaller and lighter than the instruments above mentioned.

Another form of instrument used for observing both the inclination and total force is called an "L. C." instrument. Originally designed for observations on board ships at sea, where the ordinary magnetic instruments above mentioned are unmanageable, it has also been found to give satisfactory results in a land survey, where greater accuracy is expected than at sea. Thus, during a series of observations extending from the north side of Lake Superior to the southern part of Texas last year, comparisons were made between the results obtained with an L. C. instrument and those of the regular unifilar magnetometer and dip circle, when the agreement was found satisfactory.

I am therefore of the opinion that a traveler furnished with a theodolite for land-surveying purposes, but fitted with a reversible magnetic needle, can at any time he observes a true bearing obtain a trustworthy value of the declination. Dismounting the theodolite from his tripod, the latter will serve for mounting an L. C. instrument with which to observe the inclination and force. Thus, by adding to his ordinary equipment an instrument weighing in its box about 21 pounds he can obtain valuable contributions to terrestrial magnetism and at the same time give useful assistance to geological investigations.

CONCLUDING REMARKS.

Although a great subject like terrestrial magnetism, even to exhibit our present knowledge of the science, can not be brought within the compass of an address—for it requires a treatise of many pages—I have brought some of the broad features of it before the section in order to show its connection with geography.

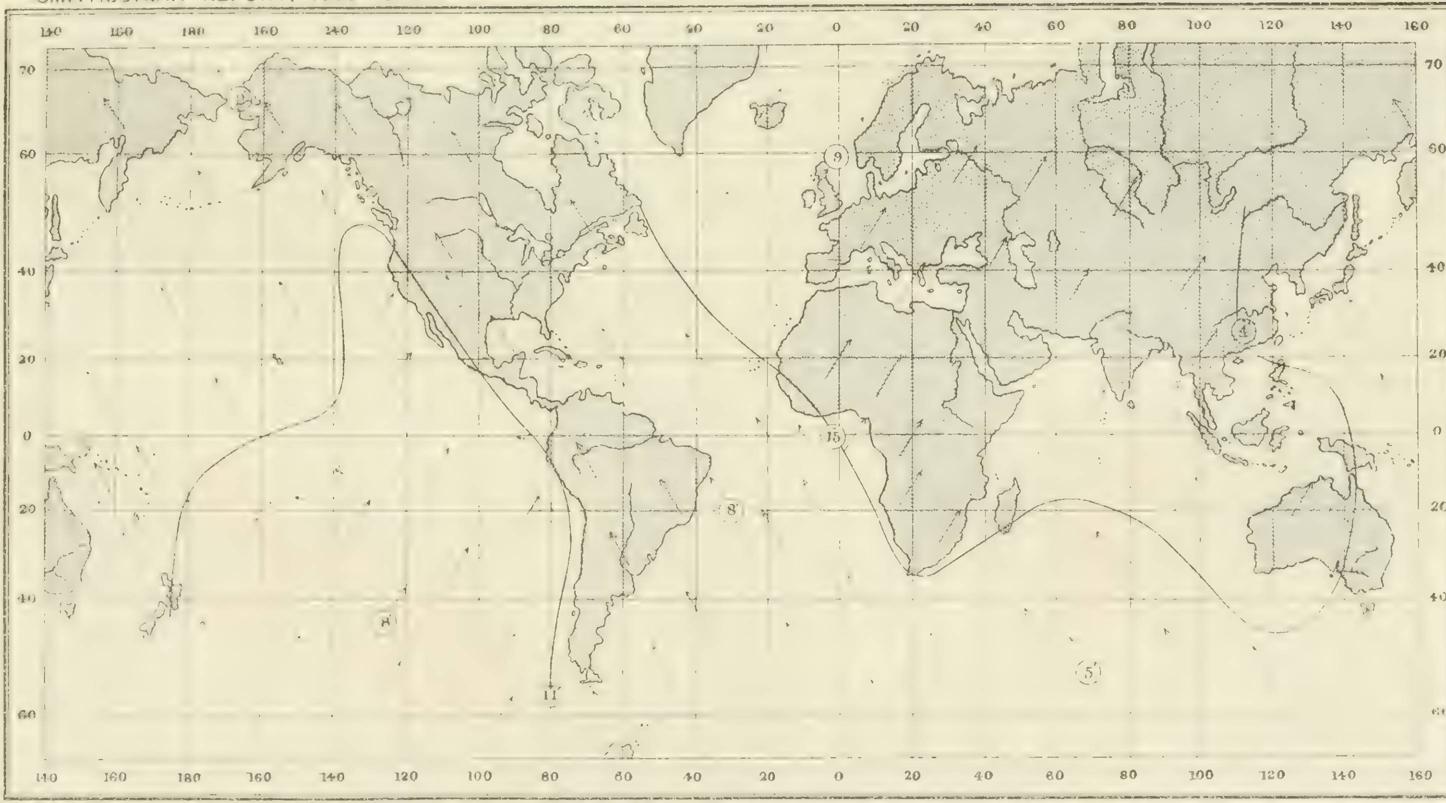
I also entertain the hope that geographers will become more interested in a subject so important to pure science and in its practical applications, and that it will become an additional subject to the instruction which travelers can now obtain under the auspices of the Royal Geographical Society in geology, botany, zoology, meteorology, and surveying.

There is a wide field open to observers, and where results often depend so much upon locality we require to explore more and more with the magnetic needle. To look over the great oceans and think how little is being done for terrestrial magnetism is a great matter for

regret. Yet even there we may begin to be more than hopeful, for the United States Coast and Geodetic Survey authorities are making arrangements to fit out its vessels with the necessary instruments for determining the magnetic elements at sea.

We wish them all success; but I must again remind you that although we can not compel observers to start, there is room for them and to spare.

I would fain make some remarks on the prevailing ignorance of sound geography in many quarters and on the defective methods of teaching the science; but I feel that the subject is placed in very able hands and will be fully discussed in Section L during the present meeting.



THE APPROXIMATE DISTRIBUTION OF THE SECULAR CHANGE IN THE MAGNETIC DECLINATION OR VARIATION. EPOCH 1840–1880

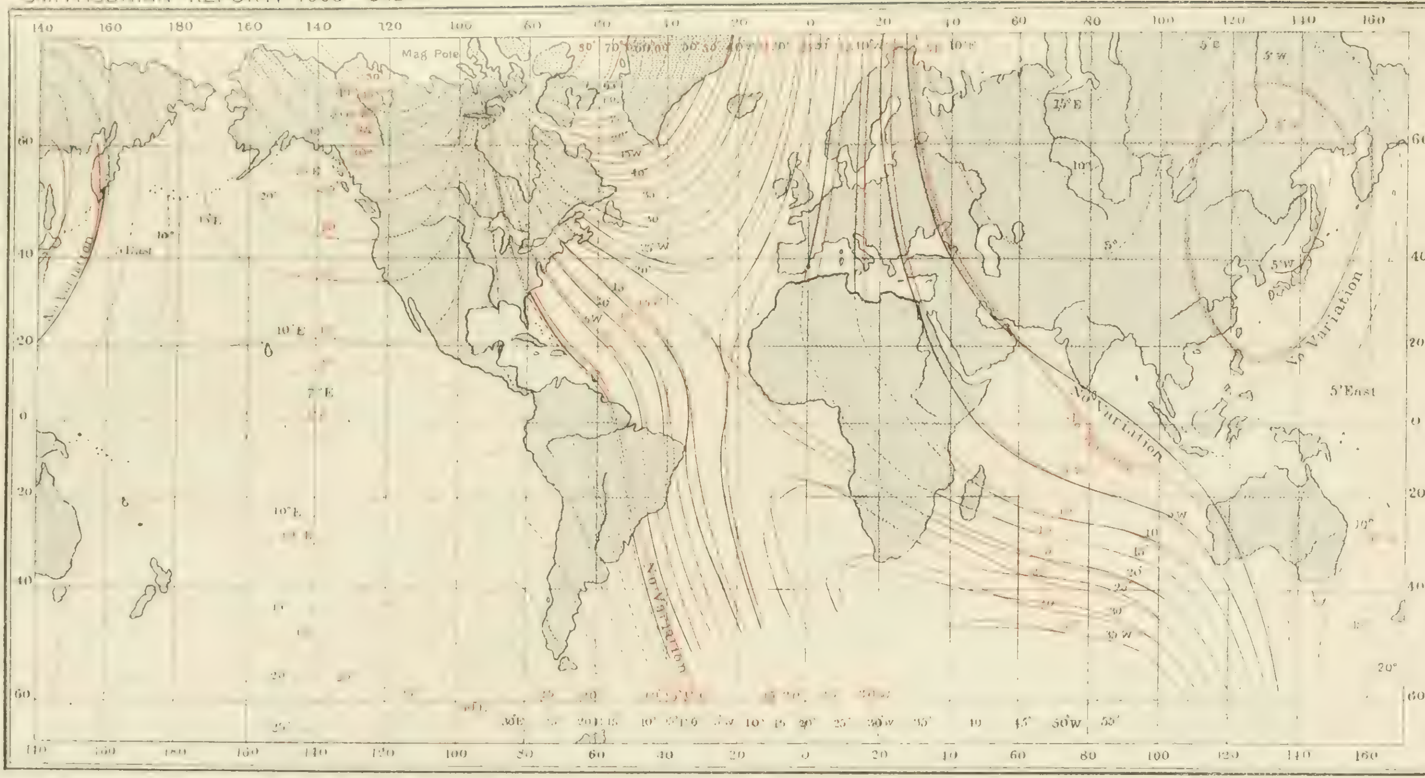
The Black curves pass through ... of the Secular change in the declination.

(5) Indicate foci of maximum Secular change, the figures giving the annual value. The arrow on the circle the direction in which the needle is moving.

(11) Are foci of maximum Secular change in the Inclination, the figures giving the annual value.

+ Signifies that the north seeking end of the needle moved downwards

− Signifies that the north seeking end of the needle moved upwards



Red lines for epoch 1880. Black lines for epoch 1895.

THE NORRIS PETERS CO. PHOTO LITHO., WASHINGTON, D.C.

MAP SHOWING LINES OF EQUAL MAGNETIC DECLINATION OR VARIATION

Showing the effects of 15 years of secular change

AN EXPLORATION TO MOUNT McKINLEY, AMERICA'S HIGHEST MOUNTAIN.[a]

By Alfred H. Brooks.

Alaska's southern shore line makes a broad, crescentic sweep, embracing that part of the northern Pacific known as the "Gulf of Alaska." Of the many indentations which give this coast its jagged outline the largest is Cook Inlet, a deep embayment in the western arm of the crescent, which stretches northward for 150 miles from the headlands marking its entrance. There it receives the turbid waters of the Sushitna River, laden with the silt of glaciers which have their source in the great Alaskan Range lying northwest of the valley. (See map, plate II.)

This Alaskan Range curves in a rugged mass around the headwaters of the Sushitna, forming the divide between the Cook Inlet drainage on the south and the waters flowing into Bering Sea through the Kuskokwim and Yukon rivers on the north. The southern end of the range lies in an unexplored region to the west of Cook Inlet, but probably does not include any peaks over 7,000 or 8,000 feet high. Toward the north its relief increases, culminating in Mount McKinley, over 20,000 feet[b] in altitude, and the highest mountain on the North American continent.

Strange as it may seem, though this mountain has been known to white men for upward of a century—it is plainly visible from tide water at Cook Inlet and from many points in the Yukon Basin—yet until very recent years it did not appear on any map and was barely referred to in literature. When the famous navigator Captain Cook in 1778 spent a few weeks exploring the inlet which now bears his name, the clouds hung low, or the mountain would not have escaped his attention.

Vancouver, fifteen years later, while extending Cook's surveys in the inlet, probably also had no view of it, though he distinctly mentions the range. The Russians, who carried on their fur trade on this

[a] Reprinted by permission from the Journal of Geography, Chicago, Vol. II, No. 9, November, 1903. Copyright, 1903, by E. M. Lehnerts.

[b] The final adjustment of surveys has not yet been made, so that the exact altitudes can not now be given.

coast for over half a century, knew the mountain and called it "Bulshaia," which, like the native name "Trolika," signified "high mountain;" but Russian literature on Alaska, so far as we know, contains no reference to this important geographical feature. Lieut. Henry T. Allen, too, who, in 1885, made his hazardous exploration of the lower Tanana, saw this peak, but at so great a distance that he was not specially impressed with its altitude.

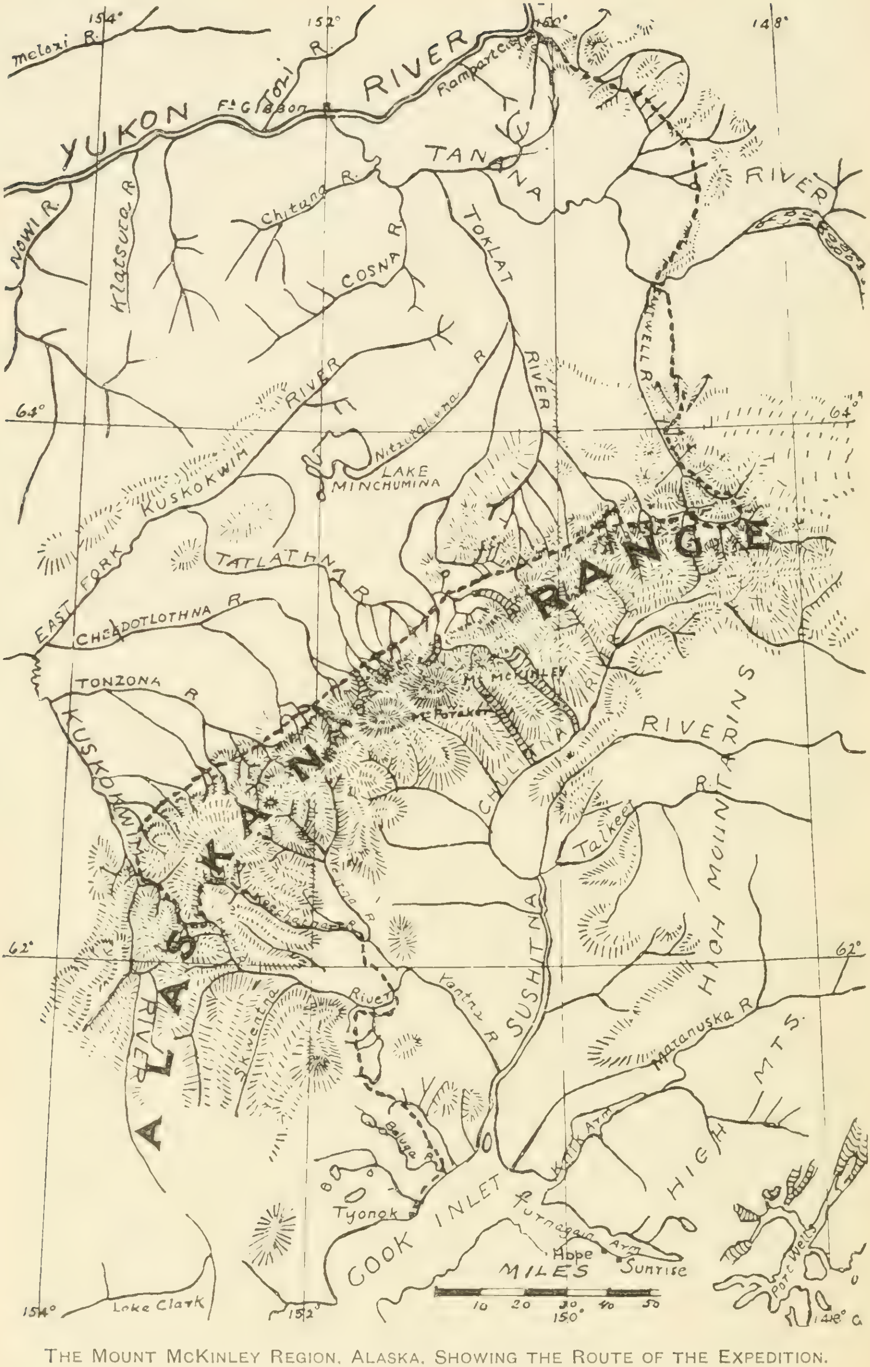
Thus it was that explorers and traders did not seem to be aware that they had sighted the highest peak on the continent. When, in 1895, scores of prospectors were attracted to Cook Inlet by the discovery of gold, they, too, saw the mountain, but apparently gave it no thought until the following year, when one of them, W. A. Dickey, recognized its importance, and upon his return published a description of it and proposed the name Mount McKinley. Though the mountain had been known to white men for over a century, and though scores of others had been as near it as this prospector, or nearer, he was termed the discoverer of Mount McKinley. All honor to him for calling attention to it, but let us not make the absurd blunder of crediting him with its discovery.

Two years after the naming of the mountain, George H. Eldridge and Robert Muldrow, of the United States Geological Survey, in the course of their exploration of the Sushitna River, located it accurately and determined its altitude at over 20,000 feet. Its height and position were thus known, and something of the character of the southern flank of the range above which it towers. The northern face of the range and the base of the mountain remained to be explored, and this was the task assigned to me as part of the general system of exploratory surveys undertaken by the Geological Survey in Alaska. I was fortunate in having as associates in this enterprise Messrs. D. L. Reaburn and L. M. Prindle, as well as four able and enthusiastic camp men.

On May 27, 1902, the vessel bearing our party steamed slowly up Cook Inlet. Hardly a ripple stirred the water, and through the hazy atmosphere we could barely discern the outline of the low coast, beyond which, in a bank of clouds, lay the high mountain range which we were to explore. At noon we dropped anchor at Tyonok, a small native settlement on the west shore of the Inlet with one trading post and a white population of half a dozen men. (See plate III.)

We were forced to wait until the evening tide floated a large scow destined to convey our horses to the shore. These, in spite of much struggling and kicking on their part, were then unceremoniously hoisted out of the hold and dropped over the side into the scow. The landing was attended with some excitement, for the horses, restless after their two week's confinement, exhibited a strong desire to leave the narrow gangway which reached the beach. One little brute satisfied his curi-

LOOKING UP AT MOUNT MCKINLEY.



THE MOUNT MCKINLEY REGION, ALASKA, SHOWING THE ROUTE OF THE EXPEDITION.

From a sketch made by the author.

osity by leaping into the sea, but was promptly hauled out, and on striking the beach took to his heels. After the entire outfit had been dragged ashore by the infinite labor of all hands, the presence of great numbers of Indians and dogs necessitated a guard, so I stood watch while the others slept. The chilly night air made the employment of chasing the Indian or "Siwash" dogs, as they are called, not unacceptable. A relief was called at 5, and I turned in and slept as one only can sleep who has been active for twenty-four hours.

The important question was which route should be chosen to the base of the mountains, for the crossing of the swampy and heavily timbered lowland area which intervened presented the most serious difficulties. The agent of the trading company, who was first interrogated, was rather skeptical of the proposed plans; and well he might be, for he had seen more than one exploring expedition start out with high hopes only to return disappointed a few months later. Should we go westward directly toward the mountains our northeasterly course along the base of the range would be blocked by glaciers; should we take a more northerly course we would become lost in a maze of swamps and encounter a number of turbulent rivers. Such were the stories told by the white men, and the Indians, who were assembled in solemn conclave, were equally discouraging.

Through the medium of signs, eked out by a few Russian words, I held a long parley with an old Indian chief over a map of his hunting grounds which he drew for me, but when I pointed out my proposed route far beyond the bounds of his knowledge he gravely shook his head as if to say that I was attempting the impossible. Some of the more experienced traders admitted that we might reach the base of the range during the course of the summer, but when we unfolded our plans for extending our journey to the Tanana, and even the Yukon, they smiled knowingly and told us when we could catch the last steamer in the fall, before the ice blocked Cook Inlet.

As a matter of fact, the "zone of influence" of many of the long-established Alaskan trading posts extends hardly a day's journey from the settlement, and many traders of long residence are astonishingly ignorant of the "hinterland." The Indian's knowledge is always confined to the hunting grounds of his tribe, and he is apt to regard the region beyond very much as the old cartographer represented unexplored areas, as the abode of hideous monsters. He magnifies unknown dangers, and this fact, together with his ignorance of the use of horses, makes his advice in regard to routes of little value.

The party paid small heed to the stories of dire failure and disaster which were recounted, for all but two of its members were veterans of three or four years' standing in Alaskan explorations and had made more than one successful trip in the face of similar gloomy prophecies. While some were reconnoitering to choose a route, the packers, Fred

and Von, were busy breaking in such of the horses as were unused to packing—an operation which afforded great amusement to the natives, who watched it from afar and promptly took to their heels if one of the bucking brutes threatened to approach them.

Our observations finally prompted us to choose the northwesterly route as the shortest, other conditions being about equal, or at least equally impossible to foresee. To facilitate the crossing of the large rivers which were known to lie athwart our route to the mountains, a boat was sent ahead in charge of George Eberhardt and Louis Anderson, both experienced in frontier life and, as the event proved, eminently reliable men. We decided not to use Indian guides, in spite of the advice of the Tyonok sages, both because of the Indian's ignorance of horses and for the reason that his insatiable appetite for white men's stores makes him an undesirable addition to a party when the transportation of supplies is the difficult problem.

The adequate provisioning of a party like ours is the most important feature of the preparation. If the allowance of food is insufficient, the journey has to be curtailed or risk of starvation encountered. On the other hand, if a greater quantity is taken than is necessary, it may hamper the transportation facilities and result in failure to the expedition. A proper variety of food is also imperative, for on this will depend the health and strength of the party. The accumulated experience of five years of Alaskan travel enabled us to judge the proportions to a nicety. Practically nothing but dried foods were chosen; the staples—flour, bacon, beans, sugar, and evaporated fruit—were supplemented by farinaceous foods, cheese, evaporated eggs and potatoes, condensed soups, together with tea, coffee, and a few pounds of delicacies, such as macaroni and jelly. Our ration provided for 3 pounds of food per man each day, an ample allowance if no canned goods are taken.

The provisions, sufficient to feed seven men for one hundred and five days, were packed in 50-pound waterproof bags. As for the rest of the equipment, everything was chosen with a view to lightness, the tents weighing only a few pounds and carbines being carried instead of rifles. Sleeping bags were substituted for blankets because they give a maximum of warmth for a minimum of weight. The entire equipment weighed about 3,500 pounds, of which 1,000 pounds were sent by boat and the rest distributed among the 20 horses.

As all our preparations were now completed and the grass was sufficiently advanced to insure an ample supply of feed for the horses, we set out from Tyonok on June 2.

At the outset our experience was a hard one. The horses were fresh and some of them objected seriously to the heavy burdens. Again and again they bucked their packs off and stampeded the entire herd. Our baggage was scattered to the four winds of heaven, and the pieces

had to be sought for carefully in the long grass which covered the upper part of the beach; the natives, meanwhile, viewing our discomfiture with delight, as if it were an exhibition prepared for their special benefit.

Beyond the town, where the route followed the beach between the water on the one side and the steep gravel bluffs on the other, the narrow space gave opportunity to control the fractious horses. (See plate III.)

The pack train was not without a certain picturesqueness. First came Fred mounted on the lead horse, and behind him, in single file, followed the other horses, their new white pack covers glistening in the sun. The other men were on foot scattered along at intervals, with George at the close of the procession, leading his small bay mare with the cook stove on top of her pack. This stove was in George's eyes the most precious possession of the party, and for three months he never allowed it to be out of his sight. It finally came to grief 700 miles inland, when both horse and stove rolled into the river.

At the mouth of the Beluga River, 20 miles from Tyonok, the boat met the party, and a day was spent in crossing. The horses were made to swim over at full tide, little relishing the plunge into the cold waters; and they probably would have liked it still less had they known of the score or more of icy rivers that would be traversed during the succeeding journey. Camp was pitched on the north bank while the boat was utilized for a two days' excursion up the Sushitna River.

Leaving the boat at an Indian town at the head of the delta, four of us made our way to Mount Sushitna. A steep climb brought us to the summit, and the broad lowland of the Sushitna Valley lay spread before us, the dark greens of its spruce forests contrasting with the lighter greens of the open marshes and the bright gleam of small lakes or winding water courses. Beyond rose a range of highlands, and then, forming the sky-line, snow-covered Alaskan mountains. From our vantage point the rugged crest line seemed unbroken, and had we not known that it was in fact cleft by passes we might have despaired of finding a route through such a forbidding mountain mass.

As we gazed a mass of clouds hanging over what appeared to be the center of the range broke and revealed two majestic peaks, Mount McKinley and Mount Foraker, glistening in the slanting rays of the afternoon sun. Far above the crest line they towered, enormous mountains, even at a distance of 120 miles. Four years before, while making an exploration down the Tanana with canoes, I had seen the same peaks and at about the same distance, but from the opposite direction.

The task before us was to find a route across the swampy lowland, traverse the mountains, and, following their northern front, approach from the inland slope as near the base of this culminating peak of the

continent as conditions and means would permit; we must map the country and incidentally explore a route which some time could be used by that mountaineer to whom should fall the honor of first setting foot on the summit of Mount McKinley.

At the Beluga River the course lay inland, and by good fortune an Indian trail lightened the labor of the axmen to a great extent; but it was designed for use in the fall and winter when the ground was frozen, and its many bogs, which then only served to facilitate traveling, now caused our horses one long struggle to wallow through it with their heavy burdens. Almost continuously one or more of the animals became mired, and often the entire strength of the seven members of the party was required to drag them out.

A week after leaving tide water, we emerged from the lowlands into a belt of foothills covered for the most part with tall grass, interspersed with symmetrical spruces and open groves of poplar. The landscape had a park-like appearance not unlike some of the farming regions of the East. (See plate IV.) The many familiar wild flowers added to the delusion, and it was hard to realize that we were in one of the unexplored parts of the world, for it seemed as if every rise of ground must bring us to the sight of a farmhouse, with its fields and orchards.

As we climbed higher we left all timber behind us except the omnipresent willow and alder thickets. The horses reveled in an abundance of grass, while the camp larder was improved by the ptarmigan which were shot along our line of march. Another glimpse of Mount McKinley enabled Reaburn, our topographer, to determine our location accurately.

The daily routine was now well established. All hands were called at 5 in the morning, and while the packers drove in the horses the others took down the tents. When the horses had been saddled and breakfast had been eaten, we all took a hand in the packing. It was no easy task to lift the 200-pound packs to the backs of the horses and adjust them. Nearly all of the men were now fairly expert at lashing them in place—"throwing the diamond hitch," as it is called. (See plate IV.) After two hours of hard work spent in this operation, the march began. In a timbered region two or three axmen preceded the train, but in the open country this was not necessary. Camp was made between 3 and 4, and after an early supper the geologist and topographer usually made an excursion to some neighboring peak or valley.

In this foothill region we came in contact with our first bear. Fred, while forging ahead of the party in search of a trail, came upon a she bear and cub. The old one at once charged. Hemmed in by alder thickets, with an ax as his only weapon, he faced his assailant with what seemed, even to an old hunter like himself, hardly a fighting

FIG. 1.—TYONOK, COOK INLET, ALASKA.

For location see map, Pl. II.

FIG. 2.—THE ROUTE ALONG THE BEACH BEYOND TYONOK.

FIG. 1.—PACKING THROUGH AN ALASKAN MEADOW LOWLAND OF TALL GRASS.

FIG. 2.—PACKING A HORSE, PREPARATORY FOR A START—"THROWING THE DIAMOND HITCH."

chance for life. Fortunately, however, the Kodiak grizzly, though larger, is not so ferocious as his Rocky Mountain brother, and Fred made his escape, though the animal approached within a few feet of him.

The good traveling came to an end all too soon, and we plunged into the thick growth of timber covering the floor of the Yentna Valley. When, on June 18, we reached the banks of that river, the turbulent, silt-bearing waters, coursing through a score of channels, did not look inviting, and we had grave doubts whether a crossing could be made. It must be attempted, however, as it would save a week's time. Mounted on two of the stronger horses, from which the saddles had been stripped, Fred and I managed to ford some of the streams, though the horses barely kept their footing in the rushing waters, which reached their shoulders. There still remained several of the widest channels. The unwilling animals were urged into the first of these, and in a moment were swept off their feet by the muddy torrent, which for an instant engulfed both riders and horses and bore them downstream at a terrific rate. By an almost instinctive movement, we threw ourselves from the struggling brutes, seized them by their manes, and swam alongside, thus at length guiding them back to the bank. We dragged ourselves out, both we and the horses shivering from our ducking in the icy waters. The plunge was but one of many similar incidents of the journey before us, but it was more significant, in that it showed the impossibility of making a crossing at this point without taking serious risks.

So, perforce, we headed downstream and spent weary days cutting a trail through the dense growth on the river bank; until on the fourth day a welcome rifle shot told us that we were near the rendezvous with the men and boat. With the aid of these we at last succeeded in crossing the river. As it was, the passage occupied an entire day, and was not without its dangers to the horses, who had to be towed across behind the boat, in imminent risk of drowning in the 8-mile current, which at times carried them under water. (See plate v.)

After agreeing upon a third rendezvous, the land party continued its trail chopping and corduroy building. This was the most disheartening part of the whole journey. The middays were sultry, and the endless chopping, harassed as we were by clouds of mosquitoes, was almost maddening. With our best efforts we could make barely 3 miles a day, and though nearly a third of our provisions were consumed, we had completed hardly an eighth of our 800-mile journey. Day after day we toiled on, fighting mosquitoes, dragging horses out of mud holes, cutting our way through dense growths of alder. Occasionally we would determine our position by compass sights from the top of some tall cottonwood, and then we would lay a new course. At last, having reason to believe ourselves near the Keechatna, we halted for a day to reconnoiter and rest the tired horses and men.

While exploring the route ahead I missed camp, which was hidden in a broad, wooded flat, and spent a part of the night in the rain, vainly attempting to snatch a few hours' sleep in spite of the myriads of mosquitoes, and my supperless plight. When I finally reached camp, at 6 the next morning, we at once got under way. A day's march brought us to the banks of the Keechatna, and a signal smoke guided us to where the boat and men awaited us. My thirty-six hours of almost continuous tramping made my small tent seem very attractive.

The Keechatna was a less turbulent stream than the Yentna, and with the aid of the boat a crossing was effected without difficulty.

We now parted with Eberhardt and Anderson, who returned to Tyonok, taking the last letters we should be able to send out. Thenceforth until we reached the Yukon, about three months later, we were to be entirely cut off from the rest of the world.

The outlook was not encouraging, for we had nearly 700 miles of practically unknown territory to traverse, and the incessant labor of toiling through the swamp, added to the continual annoyance from mosquitoes and horseflies, was having a serious effect upon the strength of our horses. Night after night we would hear the tinkle of the bell horse as he led the band of horses, maddened by the insects, back and forth. Though we blanketed them and built large fires as smudges, they seldom got relief for more than two or three hours of the twenty-four. It was terrible to see their suffering and be powerless to help them. They would frequently crowd into camp as if to implore us to relieve them from their misery.

The men, too, were becoming worn out by the mosquito pest, which harassed them continually during the day, though they found relief at night in the mosquito-proof tents. The soft blanket of moss, usually saturated with moisture, which nearly everywhere covers the face of the country, offers a breeding-ground for myriads of the insects. They are ever active, both day and night; on the mountain tops, far above timber, as well as in the lowlands. Five years of Alaskan travel have convinced me that there is no hardship so difficult to bear as this insect pest. I have seen horses, fairly maddened by the torment, blindly charge through the forest, oblivious to the trees and branches encountered, until they wore themselves out, then, in utter hopelessness, drop their heads and patiently endure the suffering. I have seen strong men, after days and nights of almost incessant torment, when they were too weary to offer further resistance to their relentless foes, weep with vexation. No part of an Alaskan traveler's outfit is more important than his mosquito-proof headdress and gloves. The former is made to fit closely around the rim of his hat and to his shoulders, for the mosquitoes will find the smallest opening. Unfortunately, the headdress has only too often to be discarded. When pushing through the undergrowth, using a surveying instrument, sighting a rifle, or chopping a trail, the traveler is at the

FIG. 1.—TOWING HORSES ACROSS THE YENTNA RIVER.

For location see map, Pl. II.

FIG. 2.—THE HEART OF THE ALASKAN RANGE.

FIG. 1.—LOOKING TOWARD RAINY PASS, THE GAP WHICH LEADS TO THE YUKON REGION.

FIG. 2.—CAMP IN THE COTTONWOODS, BELUGA RIVER.

mercy of the mosquitoes, which follow him in clouds. While every other hardship of Alaskan travel is often grossly exaggerated, it is hardly possible to do this one justice. Men capable of enduring heat and cold, hunger and fatigue without murmuring, will become almost savage under the torture. However, the story told me by an old prospector of the days on "Fortymile," when he could wave a pint cup over his head and catch a quart of mosquitoes, did seem somewhat beyond the bounds of probability.

As we could not know but that the party might be forced to retreat along the same line as the advance, we left an emergency cache of provisions at this point—that is, we placed bags of bacon and flour in the branches of a tall spruce out of the reach of wolves. There they will remain until they decay, for a cache is sacred to an Indian, and he will not molest it even if he be at the point of starvation.

On the 30th of June we started up the Keechatna River, taking turns as axmen in the dense growth of alder and willow which clothed the valley floor. Sometimes our trail lay perilously near the undercut river bank, and again it climbed along the valley wall to avoid precipitous cliffs. The river seemed to have a strange fascination for some of the horses, and more than once they deliberately jumped in. A cry for help one day brought me to the rear of the pack train on a run, and there was Prindle lying full length on a tree trunk which overhung the water, clinging desperately to the halter of a horse which the rushing current threatened to carry down. The loss would have been irretrievable, for his pack contained nearly all the records of the journey. A general alarm was sounded, and the united efforts of seven availed at last to rescue the animal.

On another occasion Medicine, one of our most troublesome horses, deliberately jumped into the river and became mired in a quicksand 20 feet from the bank. The horse following, known as "Grandfather," to whose pack was intrusted the folding boat, plunged in after Medicine, as if to the rescue. Both were dragged out, but at no small danger of both horses and men being engulfed in the treacherous quicksand.

One day the steep mountain wall closed in and forced us to ford the river. This was not very wide, but its swift current tumbling over huge bowlders looked anything but inviting. Climbing on top of a pack, I essayed the first attempt, but my horse lost his footing and rolled us both over in the icy waters. A second trial proving more successful, the other horses followed one by one, with the men lying flat on the tops of the packs. Odell, with characteristic recklessness, had chosen the wildest one, which bucked him off in midstream, giving us a bad scare, but he managed to gain his feet and clamber ashore.

After a week of this sort of thing we entered the foothills of the range, and the conditions improved. The horses being now thoroughly broken in and, in fact, almost devoid of spirit, three men could easily manage them while the others explored the adjacent hills. Grass was plentiful; and as the mosquitoes became less annoying after the timbered region was left behind, most of the horses began to recover strength.

The jaded horses now needed a day's rest, and while they enjoyed the abundant grass Reaburn and I climbed a neighboring mountain. We found that we were well within a rugged range whose jagged peaks arose on every hand and whose higher valleys were filled with glacial ice. There were still no indications of the pass we sought, so we again took up our march. (See plate v.)

On July 13 a convenient moose walked into camp, and a shot from Fred's carbine gave us a welcome supply of fresh meat. Poor Wild Bill, who had been playing the part of an invalid for several days, found himself under a load of 100 pounds, much to his disgust.

Fred, Prindle, and I now set out to explore the mountains ahead, each taking a different direction. When we met again in camp after a twenty-four hours' absence, it was Fred who reported discovery of the pass so essential to our further progress.

It was the middle of July when we threaded the narrow gap which led us from waters flowing into the Pacific Ocean to those tributary to Bering Sea. The fair weather we had encountered almost from the beginning now gave place to storms, naturally suggesting the name "Rainy Pass" for the newly discovered gap. (See plate VI.) We were now in high spirits, for we all felt that whatever the summer might bring forth, we had at least located a route through this high mountain barrier.

With this thought to encourage us we hastened to press on. Choosing as guide a stream which headed on the north side of the divide, we entered a beautiful mountain valley, whose steep slopes, clothed in dark green spruce, ended above in abrupt cliffs. Here Fred's ever-ready carbine brought us our first mountain sheep. Farther on the valley opened up into a broader one across whose level floor a mighty river meandered with great, sweeping bends, and we recognized the Kuskokwim, the second river of Alaska in size, which poured its muddy waters into the Bering Sea a thousand miles away. Here we came upon the trail of a previous exploring expedition and hailed the half-obliterated ax marks with a sense of companionship, several years old though they were.

While the pack train cut its way along the river bank, I climbed a peak which proved to be a part of the valley wall. From this point I could see the broad valley of the Kuskokwim stretching to the north, opening out 30 miles below to a broad lowland whose limits were lost in the distant haze. South of me rose the snowy peaks of the range

we had traversed, sweeping around to the northeast in an apparently unbroken crest line, without a suggestion of Rainy Pass. Far to the southwest distant snow peaks belonging to some unknown range completed the picture.

On my way down I kept along the ridge until I caught the glimmer of white tents in the valley 5,000 feet below me, and then, noting the course by my compass, I plunged down the mountain side without further consideration. A cliff proved a temporary obstacle, then another, and finally a succession of steep slopes which were merely intervals between small cliffs. Once started it was impossible to turn back; one minute I was sliding with a mass of loose talus, another cautiously clambering down a cleft in a precipice, bracing myself against either wall to maintain my scant foothold. Once a huge bowlder, which I had loosened in my descent, whizzed past and crashed into the timber a thousand feet below. It was with a deep sense of relief that I reached the timber line and registered a silent vow never to attempt anything so foolhardy again.

By the last week in July we reached the lowland which stretches northwestward from the inland front of the Alaskan Range. Our route now left the river, turning to the northwest. As we slowly cut our way through the dense timber of the lower slopes of the valley another horse gave out, and his load was distributed among the others. Poor brute! Only six weeks before he had been tearing up the beach at Tyonok, scattering his pack to right and left to the terror of the Siwash dogs.

Coming shortly after into an open spruce forest, we were startled by the discovery of a blazed trail, which was plainly not the work of natives. No one accustomed to the frontier can ever mistake the scars of an Alaskan Indian's ax, for he has never learned to make a clean, sharp cut. No; this chopping had been done by white men, in winter, several years before. We followed the trail for some miles until it turned off out of our course. Who were these lonely travelers of this wild region? Whence had they come and whither did they go? These are questions that may never be answered. That they belonged to that class of Alaskan prospectors who have traversed the territory from the almost tropical jungles of its southern coast to the barren grounds which skirt the frozen sea on the north seems not unlikely. Often these pioneers make journeys that would put to shame the widely advertised explorations of many a well-equipped government expedition. Were the results of their efforts commensurate with the toil, danger, and suffering involved, geographical science would be much enriched thereby. Unfortunately their ideas of where they have been are often almost as vague as of where they are going. Many a life has been lost on these hazardous journeys, and only too often are bleaching bones the sole record of unproclaimed and unrewarded heroism. These adventurers have no high ideals, often no

thought beyond the desire of finding gold; but in the last three decades they have been carrying civilization northward and converted an unknown land into a populated territory which is now yielding millions of gold.

From the forest we now entered a belt of foothills, which formed a northern spur of the main range, and once more obtained a clear view of Mount McKinley, still almost as far distant as when we first saw it from Mount Sushitna six weeks before. This was no cause for depression, however, for then we were separated from our goal by an apparently impenetrable swamp and a great, snow-covered range, whereas now there seemed no serious obstacles to our achieving our purpose.

Among these foothills, averaging a height of 3,000 or 4,000 feet, dwelt large numbers of mountain sheep, their pure white color, which in this region remains unchanged throughout the year, making them conspicuous objects on the bare rocks or moss-covered slopes. In the course of one morning's roaming over the hills I counted more than 100 of these mountain dwellers. In fact, the abundance of sheep, bear, moose, and caribou found along the north slope of the Alaskan Range rank it as one of the finest hunting grounds in North America.

Our descent from the foothills brought us to a gravel-floored plateau which abutted directly upon the base of the range. Its smooth, moss-covered surface afforded such excellent footing and so few obstacles to progress that for days we hardly varied our direction a degree, heading straight for Mount McKinley. That mountain and its twin peak, Mount Foraker, now only 50 miles away, seemed to us to rise almost sheer from the gravel plain. We passed many large glaciers which debouched from the mountain valleys upon the plateau and discharged roaring, turbulent, bowlder-filled rivers, which were our most serious impediment.

The other members of the party seemed to have no dread of these dangerous crossings, but for my part, I crossed every one we sighted a dozen times before we reached it. Late in the day, after the glaciers had felt the full influence of the sun's rays, the streams would often be so high as to be practically impassable, but morning would generally find the water fallen 1 or 2 feet. The large rivers were always reconnoitered on a horse stripped to the halter; then, if a crossing proved feasible, each man would mount on the back of his favorite horse and essay the perilous passage, guiding the unmanageable steed as best he could. The feat was ever exciting, with the animal plunging shoulder high in the muddy, surging water, swaying from side to side, and occasionally slipping on some hidden bowlder. More than once a horse was carried off his feet, and sometimes rolled quite over. Nor was the ludicrous aspect entirely wanting, for often when the farther bank was reached the horses would make a sudden leap for it and a

careless rider would be unceremoniously dumped over the animal's tail into the glacial water.

Since leaving the pass we had subsisted largely upon moose and mountain sheep. Not a day was spent in hunting, but when the supply of meat ran low an animal was shot near camp or on the march. Not only was game plentiful, but so little did it know of man that it regarded us rather with curiosity than mistrust. During our journey across the piedmont plateau for days and weeks together we were hardly out of sight of caribou. They had a curious way of approaching, either individually or in bands, to within 50 yards of the moving train, then galloping away to a distance and returning by a series of large circles. Sometimes a lone buck would encircle our camp for hours at a time, one minute standing erect gazing at us with rapt attention, another flying across the smooth sod at a breakneck pace, only to approach again from a different direction. Their curiosity was apparently never satisfied, their wonder ever increasing at the unfamiliar sight of the pack train or tents. Even the sharp crack of the rifle did not frighten them. There was no sport in hunting such innocently tame creatures, and we never molested them except when we needed meat.

These were the happiest days of the summer. Cheered by the thought that every day's march was bringing us visibly nearer to our goal, we lent ourselves readily to the influence of the clear, invigorating air and the inspiration of that majestic peak ever looming before us, the highest mountain of North America, which we were to be the first to explore.

Yet our task was never an easy one; for the very fact that the pack train was enabled to cover longer distances rendered it all the harder to overtake it after the side excursions which were necessary to fulfill the purpose of the expedition, and it was often dusk of the long arctic day before the geologists and topographer reached camp.

George alone of the party was low-spirited. His great ambition in life—to cook—had too narrow a scope in this land above the limit of spruce trees, where there were only stunted willow and alder for fuel. His spirits registered inversely to the barometer, rising as we went down toward timber, falling as we climbed above it. Two long journeys in the barren grounds of the north had not freed him from the traditions of the Lake Superior woodsman, and he could never regard anything as fuel that did not require splitting with an ax. Notwithstanding, he cooked wonderful meals, as the following menu copied from my diary will show:

Pea Soup.
Mountain Sheep à la George.
Rice. Potatoes.
Mince Pie. Stewed Apricots.
Johnny Cake.
Tea. Cocoa.

a meal that no city cook need be ashamed of, yet it was prepared in one of the most inaccessible points on the continent, with only green willow as fuel. George was ever faithful to his task, ready at any time of night or day with a hot meal for those who returned late.

Our camp of August 1 was pitched in a grove of cottonwoods near the foot of a glacier which flowed down from the névé fields of Mount Foraker. This we called the "Herron Glacier," in honor of Capt. Joseph S. Herron, our predecessor in the exploration of the upper Kuskokwim Basin. A short scramble through the underbrush brought me to the front of the moraine, which stretched like a cyclopean wall across the valley. Climbing to the top, I surveyed the mass spread out before me, very like the preliminary dumping ground of a railway excavation. It was a striking scene and an unusual one, for a newly formed moraine is the exception in land forms. Nature in her sculpturing delights in rounded and symmetrical outlines, and it is only when the forces of erosion have not had time to do their molding that such a crude, unfinished surface is exposed to view. It is, so to speak, the raw material which streams and rains will carve into beautifully rounded topography, and then vegetation, nature's decorative artist, will clothe with greens of various hues.

Two days later we made our nearest camp to Mount McKinley in a broad, shallow valley incised in the piedmont plateau and drained by a stream which found its source in the ice-clad slopes of the high mountain. We had reached the base of the peak, and a part of our mission was accomplished, with a margin of six weeks left for its completion. This bade us make haste, for we must still traverse some 400 miles of unexplored region before we could hope to reach even the outposts of civilization. Notwithstanding all of this, we decided to allow ourselves one day's delay, so that we might actually set foot on the slopes of the mountain. The ascent of Mount McKinley had never been part of our plan, for our mission was exploration and surveying, not mountaineering, but it now seemed very hard to us that we had neither time nor equipment to attempt the mastery of this highest peak of the continent.

The next morning dawned clear and bright. Climbing the bluff above our camp, I overlooked the upper part of the valley, spread before me like a broad amphitheater, its sides formed by the slopes of the mountain and its spurs. Here and there glistened in the sun the white surfaces of glaciers which found their way down from the peaks above. The great mountain rose 17,000 feet above our camp, apparently almost sheer from the flat valley floor. (See plate VII.) Its dome-shaped summit and upper slopes were white with snow, relieved here and there by black areas which marked cliffs too steep for the snow to lie upon.

A two hours' walk across the valley, through several deep glacial streams, brought me to the very base of the mountain. As I approached

MOUNT MCKINLEY AS SEEN THROUGH THE CLOUDS.

The camp is in the left center.

THE SLOPES OF MOUNT MCKINLEY.

the top was soon lost to view; the slopes were steep, and I had to scramble as best I could. (See plate I.) Soon all vegetation was left behind me, and my way zigzagged across smooth, bare rocks and talus slopes of broken fragments. My objective point was a shoulder of the mountain about 10,000 feet high, but at 3 in the afternoon I found my route blocked by a smooth expanse of ice. With the aid of my geologic pick I managed to cut steps in the slippery surface, and thus climbed 100 feet higher; then the angle of slope became steeper; and as the ridge on which the glacier lay fell off at the sides in sheer cliffs, a slip would have been fatal. (See plate VIII.) Convinced at length that it would be utterly foolhardy, alone as I was, to attempt to reach the shoulder for which I was headed, at 7,500 feet I turned and cautiously retraced my steps, finding the descent to bare ground more perilous than the ascent.

I had now consumed all the time that could be spared to explore this mountain, which had been reached at the expense of so much preparation and hard toil, but at least I must leave a record to mark our highest point. On a prominent cliff near the base of the glacier which had turned me back I built a cairn, in which I buried a cartridge shell from my pistol, containing a brief account of the journey, together with a roster of the party.

By this time I was forcibly reminded of the fact that I had forgotten to eat my lunch. As I sat resting from my labors I surveyed a striking scene. Around me were bare rock, ice, and snow; not a sign of life, the silence broken now and then by the roar of an avalanche loosened by the midday sun, tumbling like a waterfall over some cliff to find a resting place thousands of feet below. I gazed along the precipitous slopes of the mountain and tried to realize again its great altitude, with a thrill of satisfaction at being the first man to approach the summit, which was only 9 miles from where I smoked my pipe. No white man had ever before reached the base, and I was far beyond where the moccasined foot of the roving Indian had never trod. The Alaskan native seldom goes beyond the limit of smooth walking and has a superstitious horror of even approaching glacial ice.

Returning to camp I found Reaburn had worked all day over his plane-table board sketching the topography of the mountain, which was plainly visible from his station. His map will undoubtedly serve as a guide to him who first reaches the summit. Prindle had spent the day making an excursion into the mountains to the south of my route, and had come back burdened with geological and botanical specimens; Von and Fred had been shoeing some of the horses, while George had cooked a meal worthy of the occasion.

Our immediate goal was the Tanana River. Hoping to reach this by the valley of one of its tributaries, the Cantwell, which we believed to head in the northern part of the Alaskan Range, we continued our

course northeastward along the front of the range. The character of the country remained unchanged for 100 miles, and we pushed forward as rapidly as our surveys and investigations would permit, the long moves of the party often making it difficult for Reaburn and me to reach camp before dark. More than once we were forced to make a lonely bivouac under some spruce tree until the return of daylight enabled us to find camp. These irregularities annoyed George, who liked to see each man get a full meal three times a day. He regarded it as a kind of bad habit which we had fallen into, and when Reaburn was gone from camp for two nights in succession remarked, "When a man once takes to the spruce you can't do nothing with him."

On one occasion, after an all-day tramp, I sighted camp from a mountain top 6 miles away, its location marked by a cloud of smoke, our usual method of signaling. Crossing valleys, ridges, and lowlands, from every high point I could see the column of smoke. Darkness finally overtook me 2 miles from camp, but I held my course by sighting a star and thus made my way, breaking a passage through the thick maze of alder, stumbling over fallen logs, wading streams, and even plunging through a river whose opposite bank I could discern only in dim outline. Suddenly from the top of a ridge I saw a pillar of fire shoot toward the sky. The boys had heard my pistol shot and were putting fire into spruce trees. Thus guided by the cloud of smoke during the day and the pillar of fire by night, I finally stumbled into camp, weary, with clothing torn, and face and hands scratched by the underbrush encountered in the darkness.

About the middle of August we turned to the south again into the mountains and shortly reached the forks of the Cantwell, where two former exploring expeditions had been forced to turn back. (See plate IX.) On the following day we made what proved to be our last difficult crossing. When I saw the waters surging around the shoulders of the big horse on which I led the way I had serious fears for the smaller animals. All crossed in safety, except that Von, who had chosen a wild mount, was tossed off in shallow water, much to his disgust and the amusement of the others.

On its way to the Tanana the Cantwell cuts a deep canyon through a minor range which lies athwart its course. Finding this canyon apparently impassable for horses we began to fear that we had encountered a check; fortunately, however, a short search was rewarded by the discovery of a pass. The numerous old camps and caches showed us that this route had long been in use by the Indians, but we were the first to essay it with horses.

We came out upon the northern side of the range into the narrow valley of a stream, and from the ridge above I obtained a view over the broad lowland beyond. Far across the expanse of spruce timber and open swamp I could see the bright ribbon of water which revealed

FIG. 1.—AT THE HEAD OF THE CANTWELL RIVER.

FIG. 2.—TORTELLA ON THE TANANA.

the position of the Tanana. Meanwhile the pack train had continued down the valley below me into a rock-walled canyon, through which the stream tumbled over huge bowlders. From my point of vantage I could see through the glasses the horses climbing up the valley slopes one by one, like flies crawling up a wall. It seemed impossible that they could extricate themselves, but twenty years of mountaineering in Montana had taught Fred to take horses where no other man could. That night we camped on the Tanana side of the range and our mountain climbing was over.

Two days later the signals made to bring me to camp did not have that result, for I was miles away seeking shelter from the driving rain under a spruce tree. The rifle shots did, however, attract a band of Indians and a white prospector. The former were out on a hunting trip from their village on the Tanana. The white man, traveling alone, except for two large dogs which he had burdened with packs, was on one of those wild-goose chases after gold which are so common in Alaska. We hailed these visitors with joy, for since leaving tidewater three months before we had seen no human beings, and only once had we indication of their existence, by a smoke sighted miles away across the flats of the upper Kuskokwim.

The Indians were hungry, as is usually the case with Alaska natives, and had to be regaled. They rewarded our hospitality by information of a trail across the swampy lowland to their village on the Tanana. This was of material assistance to us, for by its aid we were enabled to cover the ground rapidly, and three days later emerged from the spruce-clothed flats on the banks of the Tanana at the native settlement called Tortella. (See plate IX.)

I reached the village some distance ahead of the party. Great was the astonishment of the natives at my sudden appearance from the forest. White men had visited them before, but always by water, in large parties and with abundant supplies. Who was the lone stranger whose baggage consisted solely of his revolver, field glasses, and hammer, and where did he come from? One boy knew some English, and, drawing a map in the sand by way of illustration, I explained my route, greatly to their bewilderment. One old man had made the trip to Cook Inlet years ago, but he had gone by the direct route from the head of the Cantwell, and they knew nothing of the roundabout route we had followed.

The village consisted of a score of low structures built of spruce logs, each containing two or more families. The fire was built in the center and a hole in the roof served in lieu of a chimney. At night the occupants lay on either side of the fire with their feet toward it, warmly covered with caribou skins. Their clothing consisted chiefly of articles procured from the trading post on the Yukon 100 miles away, imparting an aspect that was ludicrous rather than picturesque. The old

chief gravely stalked around, peering out from under the visor of a policeman's helmet, which was so large for him that is rested on his ears.

When the horses arrived their delight and somewhat childish terror were laughable. Losing no time, we bargained with the Indians for a boat and began the crossing. After one horse had been towed over, the rest were driven in and swam across to join their mate. Thus by nightfall we were camped on the north bank.

It was now the 1st of September and we were still 100 miles or more from our goal on the Yukon. The Indians implored us not to attempt to make the journey by land, declaring the country impassable for horses. As my interpreter stated the case, "Plenty water; plenty stick [thick timber]. No good! No good!" But we were not to be deterred from completing the exploration we had planned, though we could have shot the horses and easily reached the Yukon by boat. The next morning a delegation of our friends visited our camp to give us a final warning: "No good! No good! By and by come back. Maybe so."

Here we abandoned all except the most necessary part of our outfit, for the early frost was killing the grass and the stock was beginning to show the effects of insufficient nourishment. The light packs were quickly adjusted, and without cutting a trail, to the astonishment of the Indians, we let the horses crash their way through the underbrush. For two days we followed a ridge leading to the north along the eastern edge of a broad timbered flat dotted with innumerable lakes and crossed by many sluggish water courses. This it was that the Indians had said was impassable. Finding that the route around it threatened to protract our journey 100 miles or more, we boldly headed straight across it.

It was a route beset with difficulties. Now we were chopping our way through a dense tangle of small growth; now building corduroy over swamps and streams; now rafting rivers too wide to bridge. All worked with energy born of the consciousness that our provisions were getting low and it was only a matter of days before our horses would begin to play out. In one week we succeeded in rafting five rivers and built bridges over six more. More than once our temporary bridge gave way, and then we had the heartrending toil of dragging the poor, weak animals up on the bank. The traveling was not all of this character, for occasionally there would be a stretch of several miles where we would thread our way through open forests of white birches. The glistening white trunks and yellow autumnal foliage presented a gayety of color which was in strong contrast to the somber spruce forest we had been traversing for so many miles. The small lakes were covered with wild fowl congregating for their southward migration.

We finally left the lowland and entered an upland region, where we kept for the most part above timber. The poor horses, even under the lightened loads, began to fail. Overtaking the pack train one day, I found Prindle and George laboring with Rabbit, who refused to take another step. Both were very fond of the little mare—always a pet with the party—and wanted to save her life. We worked with her a while, but it was no use—her heart was broken; and drawing my revolver, I sent a bullet through the brain of the poor beast who had served us so well. After this a horse was shot nearly every day.

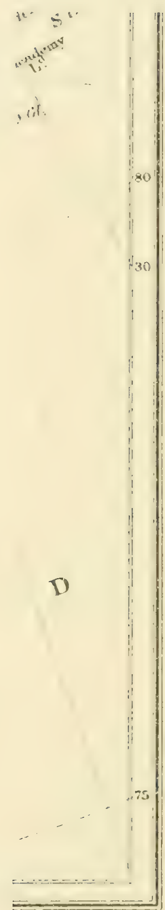
Leaving the party one morning, I took a long side trip, expecting to pick up their trail and follow it into camp that night, but they had misunderstood my directions, and at midnight I again sought shelter from the rain under a large spruce. I roasted a ptarmigan which I had shot, and this, together with a few hard-tack, constituted my supper and breakfast. The next day I was forced to go back to the old camp to pick up the trail. A dead horse marked the spot, and a search through his pack revealing a bag of rice, I cooked a meal of this with the aid of an abandoned butter can and started on the trail. On the mountain side lay another dead horse with some bacon left in his pack, which I took for an emergency. Nightfall found me not yet in camp, and this time I dined and breakfasted on bacon and another ptarmigan which had fallen to my revolver. Late in the afternoon I reached camp, after an absence of two nights and nearly three days, to find Reaburn very anxious and scouts out in various directions. This camp was on a trail which led from the then newly discovered gold diggings known as Glenn Creek to Rampart, on the Yukon.

The next morning we packed for the last time, abandoning most of the outfit and feeding the last of our flour to the horses to strengthen them for the final march. I took a route across the hills and at nightfall joined the party camped in the town of Rampart. Many were the questions asked us, but few of the questioners, I think, really believed that we had made the journey from Cook Inlet.

Thus ended the longest cross-country exploration ever attempted in Alaska. Our plans had been carried out from start to finish; we had traversed 800 miles of the roughest part of Alaska in one hundred and five days. While cooking our breakfast next morning, a river steamer whistled, the last to make the journey down the Yukon before it was locked in the winter ice. Leaving our breakfast cooking on the fire, we hastily gathered up our more precious belongings, chiefly notes and specimens, and scrambled on board. The boat swung out in midstream, and with a farewell salute to the crowd of Indians and prospectors on the bank we rapidly steamed away, once more headed for civilization and home.

SMITHSONIAN REPORT. 1903—PEARY. PLATE I.

FROM THE GEOGRAPHICAL JOURNAL, LONDON, DECEMBER, 1903.



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NORTH POLAR EXPLORATION: FIELD WORK OF THE PEARY ARCTIC CLUB, 1898–1902.[a]

By Commander R. E. PEARY, U. S. Navy.

INTRODUCTION.

In January, 1897, I promulgated before the American Geographical Society of New York City my plan for an extended scheme of arctic exploration, having for its main purpose the attainment of the North Pole. During the spring of 1897 Morris K. Jesup, now president of the Peary Arctic Club, became interested in the matter and suggested the idea of this club. His example was followed by other prominent men, and late in May, through the persistent personal efforts of Charles A. Moore, backed by letters from these and other influential men, five years' leave of absence was granted me by the Navy Department to enable me to carry out my plans.

It being too late that season to get the main expedition under way, the summer of 1897 was devoted to a preliminary trip to the Whale Sound region to acquaint the Eskimos with my plan for the coming year and in setting them to work laying in a stock of skins and meat. These objects were successfully accomplished, and, in addition, the great "Ahnighito" meteorite of Melville Bay, the largest known meteorite in the world, was brought home. In December, 1897, while in London, the schooner yacht *Windward*, which had been used in his Franz Josef Land expedition, was tendered to me by Alfred Harmsworth, who offered to have her re-engined and delivered to me in New York. This generous offer I accepted. In the spring of 1898 the Peary Arctic Club was organized, Morris K. Jesup, Henry W. Cannon, H. L. Bridgman, all personal friends of mine, forming the nucleus about which the rest assembled. In May the *Windward* arrived, but to my extreme regret and disappointment she still retained her antiquated and puny engine (the machinists' strike in England prevented the installation of new ones), and was practically nothing but a sailing craft. The lateness of the season was such that nothing could be done but

[a] From manuscript, as read before the Peary Arctic Club, by courtesy of the National Geographic Society.

make the most of the *Windward* as she was. But her extreme slowness ($3\frac{1}{2}$ knots under favorable circumstances) and the introduction of a disturbing factor, in the appropriation by another of my plan and field of work, necessitated the charter of an auxiliary ship if I did not wish to be distanced in my own domain. The *Windward* sailed from New York on the 4th of July, 1898, and on the 7th I went on board the *Hope* at Sydney, Cape Breton, and sailed just as the first two-line cablegram came of the battle of Santiago.

1898–99.

Pushing rapidly northward and omitting the usual calls at the Danish Greenland ports, Cape York was reached after a voyage uneventful except for a nip in the ice of Melville Bay which lifted the *Hope* bodily and for a few hours seemed to contain possibilities of trouble. The work of hunting walrus and assembling my party of natives was commenced at once; the *Windward* soon joined us, after which the hunting was prosecuted by both ships until the final rendezvous at Etah, from whence both ships steamed out on August 13, the *Windward* to continue northward, the *Hope* bound for home. The *Windward* was four hours forcing her way through a narrow barrier of heavy ice across the mouth of Foulke Fjord. Here the *Hope* left us, straightening away southward toward Cape Alexander, and the *Windward* headed for Cape Hawkes, showing distinctly beyond Cape Sabine. At 4 a. m. Sunday we encountered scattered ice off Cape Albert. About noon we were caught in the ice near Victoria Head, and drifted back several miles. Finally we got round Victoria Head into Princess Marie Bay at 6 p. m. The bay was filled with the season's ice, not yet broken out, while Kane Basin was crowded with the heavy, moving polar pack. Between the two, extended northward across the mouth of the bay, was a series of small pools and threads of water, opening and closing with the movements of the tide. At 11.30 p. m. on the 18th the *Windward* had worried her way across the bay to a little patch of open water close under Cape D'Urville. Here further progress was stopped by a large floe, several miles across, one end resting against the shore and the other extending out into the heavy ice. While crossing the bay the more important stores had been stowed on the deck in readiness to be thrown out upon the ice in the event of a nip. Pending the turning of the tide, when I hoped the big floe would move and let us proceed, I landed at Cape D'Urville, deposited a small cache of supplies, and climbed the bluffs to look at the conditions northward.

August 21.—I went on a reconnoissance along the ice foot to the head of Allman Bay and into the valley beyond. The night of the 21st young ice formed which did not melt again. On the 28th I attempted to sledge over the sea ice to Norman Lockyer Island, but found too

many weak places, and fell back on the ice foot. The night of the 29th the temperature fell to 13° F., and on the 31st the new ice was 4¼ inches thick. On this day I went to Cape Hawkes and climbed to its summit, whence I could see lakes out in Kane Basin, but between them and the *Windward* the ice was closely packed—a discouraging outlook. Only a strong and continued westerly wind would give me any chance. The uncertainty of these two weeks was very annoying to me. Had I been sure that we could not get away from here I could have been making an inland trip. As it was I could not leave the ship for fear an opportunity to advance would occur in my absence.

September 2.—I started on a sledge trip up Princess Marie Bay. At Cape Harrison the strong tidal current kept the ice broken, so I could not round it, and the ice foot was impracticable for sledges. I went on foot to the entrance of Copes Bay, surveying the shore to that point, then returned to the ship after four days' absence. During this trip I obtained the English record from the cairn on the summit of Norman Lockyer Island, deposited there twenty-two years ago. This record was as fresh as when left.

September 6.—I left the ship to reconnoiter Dobbin Bay, the head of which is uncharted, returning three days later. During this trip the first real snowstorm of the season occurred, 5½ inches falling.

September 12.—One-third of my provisions, an ample year's supply for the entire party, was landed at Cape D'Urville, my Eskimos sledging loads of 700 to 1,000 pounds over the young ice. The night of the 13th the temperature dropped to —10° F., and all hope of farther advance was at an end.

September 15.—The boiler was blown off and preparations for winter commenced.

On the 17th I broached my plans for the winter campaign as follows:

The autumn work was simple enough and outlined itself. It comprised two items—the securing of a winter's supply of fresh meat for the party and the survey of the Buchanan Strait-Hayes Sound-Princess Marie Bay region. In spite of the peculiarly desolate character of that part of the Grinnell Land coast immediately about the *Windward*, and the apparent utter absence of animal life, I felt confident of accomplishing the former. Various reconnoissances thus far on the north shore of Princess Marie Bay had given me little encouragement, but I knew that the Eskimos had killed one or two musk oxen in years past on Bache Island, and that region looked favorable for them. As regards the survey, a presentiment that I must get at that at the earliest possible moment had already led me to make attempts to reach the head of Princess Marie Bay.

As to the spring campaign, I could not be reconciled to the idea of losing a year from the main work of the expedition, and proposed to

utilize the winter moons in pushing supplies to Fort Conger, then move my party to that station early in February, and on the return of the sun start from there as a base, and make my attempt on the Pole via Cape Hecla. I might succeed in spite of the low latitude of my starting point, and in any event could be back to the ship before the ice broke up, with thorough knowledge of the coast and conditions north of me.

September 18.—I left the ship with two sledges and my two best Eskimos, with provisions for twelve days, for a reconnoissance of Princess Marie Bay.

September 20.—I reached the head of a small fjord running southwest from near the head of Princess Marie Bay, and found a narrow neck of land about 3 miles wide separating it from a branch of Buchanan Strait. Bache Island of the chart is, therefore, a peninsula, and not an island. From a commanding peak in the neighborhood I could see that both arms of Buchanan Strait ended about south of my position; that the "strait" is in reality a bay, and that Hayes Sound does not exist. On the 21st and 22d I penetrated the arms of Princess Marie Bay, designated as Sawyer and Woodward bays on the charts, and demonstrated them to be entirely closed.

September 23.—While entering a little bight about midway of the north shore of Bache Peninsula, I came upon two bears. These my dog chased ashore, and held at bay until I could come up and kill them.

September 25.—I crossed Bache Peninsula on foot with my two men, from Bear Camp to the intersection of the northern and southern arms of Buchanan Bay. Here we found numerous walrus, and could command the southern arm of the large glacier at its head. Comparatively recent musk-ox tracks convinced me of the presence of musk ox on the peninsula. The next day I returned to the *Windward* to refit and start for Buchanan Bay via Victoria Head and Cape Albert, in the quest of walrus and musk oxen. Henson, in a reconnoissance northward during my absence, had been unable to get more than a few miles beyond Cape Louis Napoleon, sea ice and ice foot being alike impracticable. A day or two after my return I started him off again to try it.

September 30.—I started for Buchanan Bay. Between Victoria Head and Cape Albert found fresh tracks of a herd of musk oxen and followed them until obliterated by the wind. Reached the walrus grounds in Buchanan Bay late on October 4, and the next day secured a walrus, and the remainder of my party arrived. The following day everyone was out after musk oxen, but, finding it very foggy on the uplands of the peninsula, I returned to camp and went up to Buchanan Bay in search of bears, the tracks of which we had seen. Returning to camp, I found that one of my hunters had killed a bull musk ox.

FIG. 1.—LANDING SUPPLIES AT CAPE D'URVILLE.

FIG. 2.—WINTER QUARTERS AT CAPE D'URVILLE, 1898-99.

FIG. 1.—CAPE LAWRENCE.

FIG. 2.—CAPE LOUIS NAPOLEON.

On the 7th of October I sent two men to bring out the meat and skin, while I went up Buchanan Bay again. Returning to camp, I found it deserted. A little later some of my party returned, reporting a herd of 15 musk oxen killed. The next two days were consumed in cutting up the animals, stacking the meat, and getting the skins and some of the meat out to camp. The latter had to be dragged to the top of the bluffs and thrown over.

October 10.—We started for the ship, which was reached late on the 12th. The ice in Buchanan Bay was very rough, and a snowstorm on the 11th made going very heavy. Five days later, October 17, I went with two men to locate a direct trail for getting the meat out to the north side of the peninsula, but found the country impracticable, and returned to the ship on the 21st. The sun left on the 20th.

The following week was devoted to the work of preparation for the winter. A reconnoissance of Franklin Pierce Bay developed nothing but hare tracks, but Henson came in from Copes Bay with a big bear, killed near the head of the bay. This marked the end of the fall campaign, with our winter's fresh meat supply assured, and the Bache "Island"-Buchanan "Strait"-"Hayes Sound" question settled.

The next step was the inauguration of the teaming work, which was to occupy us through the winter. I already had my pemmican and some miscellaneous supplies at Cape Louis Napoleon, and two sledge loads of provisions at Cape Fraser. The rapidly disappearing daylight being now too limited for effective traveling, I was obliged to wait the appearance of the next moon before starting for a personal reconnoissance of the coast northward. On the 29th I left the ship with Henson and one Eskimo. The soft snow of the last two storms compelled me to break a road for the sledges with my snowshoes across Allman Bay and along many portions of the ice foot, but in spite of this delay we camped at Cape Louis Napoleon after a long march.

The next day we reached Cape Fraser, having been impeded by the tide rising over the ice foot, and camped at Henson's farthest, at the beginning of what seemed an impracticable ice foot. It was the only possible way of advance, however, as the still moving pack in the channel was entirely impassable. The following day I made a reconnoissance on foot as far as Scoresby Bay, and though the ice foot was then entirely impracticable for sledges, I was convinced that a good deal of earnest work with picks and shovels, assisted by the leveling effects of the next spring tides, would enable me to get loaded sledges over it during the next moon. From Cape Norton Shaw I could see that by making a detour into Scoresby Bay the heavy pack could be avoided in crossing. This stretch of ice foot from Cape Fraser to Cape Norton Shaw is extremely Alpine in character, being an almost continuous succession of huge blocks and masses of bergs and old floes,

forced bodily out of the water and up onto the rocks. At Cape John Barrow a large berg had been forced up on the solid rock of the cape, until one huge fragment lay fully 100 feet above the high-tide level.

Returning from my reconnoissance, I camped again at Camp Fraser, building the first of my snow igloos, which I intended should be constructed at convenient intervals the entire distance to Fort Conger. The next three days were occupied in bringing the supplies at Cape Louis Napoleon up to Cape Fraser, and on the 4th of November I returned to the ship. The time until the return of the next moon was fully occupied in making and repairing sledges, bringing in beef from the cache on Bache Peninsula, and transporting supplies and dog food to Cape Hawkes, beyond the heavy going of Allman Bay. During much of this time the temperature was in the —40°'s F.

November 21.—Henson and 3 Eskimos left with loads, and on the 22d I followed with a party of 3 to begin the work of the November moon. This work ended just after midnight of December 4, when the last sledges came in. It left 3,300 pounds of supplies and a quantity of dog food at Cape Wilkes on the north side of Richardson Bay. These supplies would have been left at Cape Lawrence had it not been for the desertion and turning back of one of my men, discouraged with the hard work, while crossing Richardson Bay. Knowing it to be essential to prevent any recurrence of the kind, I pushed on to Cape Wilkes, camped, and turned in after a twenty-five-hour day, slept three hours, then started with empty sledge, 8 picked dogs, and an Eskimo driver, to overtake my man. He was found at Cape Louis Napoleon, and after receiving a lesson was taken along with me to the ship.

My party was left with instructions to bring up supplies which the wrecking of sledges had obliged me to cache at various places, assemble all at Cape Wilkes, and then, if I did not return, reconnoiter the ice foot to Rawlings Bay and return to the ship. The distance from Cape Wilkes to the *Windward* was 60 nautical miles in a straight line (as traveled by me along the ice foot and across the bays, not less than 90 statute miles), and was covered in twenty-three hours and twenty minutes, or twenty-one hours and thirty minutes actual traveling time. Temperature during the run, —50° F. Every sledge was more or less smashed in this two weeks' campaign, and at Cape John Barrow sledges and loads had to be carried on our backs over the ice jams. The mean daily minimum temperature for the thirteen days was —41.2 F., the lowest, —50° F., which occurred on four successive days. The experience gained on this trip led me to believe that the conditions of travel from Cape Wilkes northward, as far at least as Cape Defosse, would not differ materially from those already encountered and enabled me to lay my plans with somewhat greater detail. With the light of the December moon I would proceed to Cape Wilkes with such loads as would enable me to travel steadily without double banking, advance

everything to Cape Lawrence on the north side of Rawlings Bay, then go rapidly on to Fort Conger with light sledges, determine the condition of the supplies left there, that I might know what I could depend upon, and thus save transportation of unnecessary articles, then return to the ship.

In the January moon I would start with my entire party; move my supplies from Cape Lawrence to Fort Conger; remain there till the February moon, the light of which would merge into the beginning of the returning daylight; then sledge the supplies for the polar journey to Cape Hecla, and be in readiness to start from there, with rested and well-fed dogs, by the middle of March. In pursuance of this plan, the two weeks intervening between the departure of the November moon and the appearance of the December one were busily occupied in repairing and strengthening sledges, and making and overhauling clothing and equipment, to enable us to meet this long and arduous journey in the very midnight of the "great night." During this interval the temperature much of the time was at $-50°$ F. and below.

December 20.—In the first light of the returning moon I left the *Windward* with my doctor, Henson, 4 Eskimos, and 30 dogs, all that were left of the sixty odd of four months previous. Thick weather, strong winds rushing out of Kennedy Channel, heavy snow, and an abominable ice foot in Rawlings Bay delayed me, and it was not until the 28th that I had all my supplies assembled at Cape Lawrence, on the north side of Rawlings Bay.

Cape Lawrence presented the advantage of two possible routes by which these latter supplies could be reached from Conger, one through Kennedy Channel, which I was about to follow, and the other via Archer Fjord and overland. In spite of the delays, I felt on the whole well satisfied with the work up to the end of the year. I had all my supplies halfway to Fort Conger, and had comfortable snow igloos erected at Cape Hawkes, Cape Louis Napoleon, Cape Fraser, Cape Norton Shaw, Cape Wilkes, and Cape Lawrence.

December 29.—I started from Cape Lawrence with light sledges for Fort Conger, hoping to make the distance in five days. The first march from Cape Lawrence the ice foot was fairly good, though an inch or two of efflorescence made the sledges drag as if on sand. The ice foot grew steadily worse as we advanced, until after rounding Cape Defosse, it was almost impassable even for light sledges. The light of the moon lasted only for a few hours out of the twenty-four, and at its best was not sufficient to permit us to select a route on the sea ice.

Just south of Cape Defosse we ate the last of our biscuit, just north of it the last of our beans. On the next march a biting wind swept down the channel and numbed the Eskimo, who had spent the previous winter in the States, to such an extent that to save him we were

obliged to halt just above Cape Cracroft and dig a burrow in a snow-drift. When the storm ceased I left him with another Eskimo and 9 of the poorest dogs and pushed on to reach Fort Conger.

The moon had left us entirely now, and the ice foot was utterly impracticable, and we groped and stumbled through the rugged sea ice as far as Cape Baird. Here we slept a few hours in a burrow in the snow, then started across Lady Franklin Bay. In complete darkness and over a chaos of broken and heaved-up ice we stumbled and fell and groped for eighteen hours, till we climbed upon the ice foot of the north side. Here a dog was killed for food. Absence of suitable snow put an igloo out of the question, and a semicave under a large cake of ice was so cold that we could stop only long enough to make tea. Here I left a broken sledge and 9 exhausted dogs. Just east of us a floe had been driven ashore, and forced up over the ice foot till its shattered fragments lay 100 feet up the talus of the bluff. It seemed impassable, but the crack at the edge of the ice foot allowed us to squeeze through; and soon after we rounded the point, and I was satisfied by the "feel" of the shore, for we could see nothing, that we were at one of the entrances of Discovery Harbor, but which one I could not tell. Several hours of groping showed that it was the eastern entrance. We had struck the center of Bellot Island, and at midnight of January 6 we were stumbling through the dilapidated door of Fort Conger. A little remaining oil enabled me, by the light of our sledge cooker, to find the range and the stove in the officers' quarters, and after some difficulty fires were started in both. When this was accomplished, a suspicious "wooden" feeling in my right foot led me to have my kamiks pulled off, and I found to my annoyance that both feet were frosted. Coffee from an open tin in the kitchen, and biscuit from the table in the men's room, just as they had been dropped over fifteen years ago, furnished the menu for a simple but abundant lunch. A hasty search failing to discover matches, candles, lamps, or oil, we were forced to devise some kind of a light very quickly before our oil burned out. Half a bottle of olive oil, a saucer, and a bit of towel furnished the material for a small native lamp, and this, supplemented by pork fat and lard, furnished us light for several days, until oil was located. Throwing ourselves down on the cots in the officers' rooms, after everything had been done for my feet, we slept long and soundly. Awakening, it was evident that I should lose parts or all of several toes, and be confined for some weeks. The mean minimum temperature during the trip was -51.9° F., the lowest -63° F.

During the following weeks our life at Conger was pronouncedly à la Robinson Crusoe. Searching for things in the unbroken darkness of the "Great Night," with a tiny flicker of flame in a saucer, was very like seeking a needle in a haystack. Gradually all the essentials were located, while my 2 faithful Eskimos brought in empty boxes

and barrels and broke them up to feed the fire. The dogs left on Bellot Island were brought in, but several died before they got used to the frozen salt pork and beef, which was all I had to feed them. The natives made two attempts to reach and bring in the 2 men left at Cape Cracroft, but were driven back both times by the darkness and furious winds. Finally, some ten days after we left the dugout, they reached it again, and found that the 2 men, after eating some of their dogs, had started for the ship on foot, the few remaining dogs following them.

On the 18th of February the moonlight and the remaining twilight afforded enough light for a fair day's march in each twenty-four hours; we started for the *Windward*. My toes were unhealed, the bones were protruding through the raw stumps on both feet, and I could hardly stand for a moment. I had 12 dogs left, but their emaciated condition and the character of the road precluded riding by anyone but myself. Lashed firmly down, with feet and legs wrapped in musk-ox skin, I formed the only load of one sledge. The other carried the necessary provisions.

On the 28th we reached the *Windward*, every one but myself having walked the entire distance of not less than 250 miles in eleven days. Fortunately for us, and particularly for me, the weather during our return, though extremely cold, was calm, with the exception of one day from Cape Cracroft south, during which the furious wind kept us enveloped in driving snow. The mean minimum daily temperature while we were returning was $-56.18°$ F., reaching the lowest, $-65°$ F., the day we arrived at the *Windward*.

March 3.—I started one of my Eskimos for Whale Sound with a summons to the hunters there to come to me with their dogs and sledges. Between the 3d and 14th a party of Eskimos coming unexpectedly, the last of the musk-ox meat on Bache Peninsula was brought to the ship, and another bull musk ox killed.

March 13.—The final amputation of my toes was performed. Pending the arrival of more natives, I sent a dory to Cape Louis Napoleon to be cached and had dog food and current supplies advanced to Cape Fraser.

March 31.—A contingent of 5 natives and 27 dogs came in. My messenger had been delayed by heavy winds and rough ice, and the ravages of the dog disease had made it necessary to send to the more southerly settlements for dogs.

April 3.—Henson left with these natives and 35 dogs, with instructions to move the supplies at Cape Lawrence to Carl Ritter Bay, then push on with such loads as he could carry without double banking to Fort Conger, rest his dogs and dry his clothing, and if I did not join him by that time to start back.

April 19.—My left foot had healed, though still too weak and stiff from long disuse for me to move without crutches. On this day I started for Fort Conger with a party of 10, some 50 dogs, and 7 sledges loaded with dog food and supplies for return caches.

April 23.—I met Henson returning with his party at Cape Lawrence. From there I sent back my temporary help and borrowed dogs, and went on with a party of 7, including 5 natives.

April 28.—We reached Conger.

May 4.—Having dried all our gear and repaired sledges, I started for a reconnoissance of the Greenland northwest coast. I should have started two days earlier but for bad weather. Following a very arduous ice foot to St. Patricks Bay, I found the bay filled with broken pack ice covered with snow almost thigh deep. From the top of Cape Murchison, with a good glass, no practicable road could be seen. The following day I sent 2 men with empty sledges and a powerful team of dogs to Cape Beechy to reconnoiter from its summit. Their report was discouraging. Clear across to the Greenland shore, and up and down as far as the glass could reach, the channel was filled with upheaved floe fragments, uninterrupted by young ice or large floes, and covered with deep snow.

Crippled as I was, and a mere dead weight on the sledge, I felt that the road was impracticable. Had I been fit and in my usual place, ahead of the sledges breaking the ice with my snowshoes, it would have been different. One chance remained—that of finding a passage across to the Greenland side at Cape Lieber.

Returning to Conger, I sent Henson and one Eskimo off immediately on this reconnoissance, and later sent 2 men to Musk Ox Bay to look for musk oxen. Two days afterward they returned reporting 16 musk oxen killed, and Henson came in on the same day, reporting the condition of the channel off Capes Lieber and Cracroft the same as that off Capes Beechy and Murchison, and that they had been unable to get across. I now gave up the Greenland trip, and perhaps it was well that I did so, as the unhealed place on my right foot was beginning to break down and assume an unhealthy appearance from its severe treatment. As soon as the musk-ox skins and beef were brought in, the entire party, except myself and one Eskimo, went to the Bellows and Black Rock Vale for more musk oxen. Twelve were killed here, and the skins and meat brought to Conger. Not believing it desirable to kill more musk oxen, and unable to do any traveling north, I completed the work of securing the meat and skins obtained; getting the records and private papers of the United States International Expedition together; securing, as far as possible, collections and property; housing material and supplies still remaining serviceable, and making the house more comfortable for the purposes of my party.

May 23.—We started for the ship, carrying only the scientific records of the expedition, the private papers of its members, and necessary supplies. I was still obliged to ride continuously. Favored with abundant light and continuously calm weather, and forcing the dogs to their best, the return to the ship was accomplished in six days, arriving there May 29. During my absence Captain Bartlett had built at Cape D'Urville, from plans which I had furnished him, a comfortable house of the boxes of supplies, double roofed with canvas, and banked in with gravel.

June 1.—I sent one sledge load of provisions to Cape Louis Napoleon, and four to Cape Norton Shaw.

June 6.—I sent three loads to Carl Ritter Bay and two to Cape Lawrence. On the 25th of June the last of these sledges returned to the *Windward*, and the year's campaign to the north was ended. The return from Carl Ritter Bay had been slow, owing to the abundance of water on the ice foot and the sea ice of the bays, and the resulting sore feet of the dogs.

June 28.—A sufficient number of dogs had recovered from the effect of their work to enable me to make up two teams, and Henson was sent with these, four of the natives, and a dory, to make his way to Etah and communicate with the summer ship immediately on her arrival, so that her time would not be wasted even should the *Windward* be late in getting out of the ice.

June 29.—I started with two sledges and three natives to complete my survey of Princess Marie and Buchanan bays, and make a reconnoissance to the westward from the head of the former. My feet, which I had been favoring since my return from Conger, were now in fair condition, only a very small place on the right one remaining unhealed. Traveling and working at night and sleeping during the day, I advanced to Princess Marie Bay, crossed the narrow neck of Bache Peninsula, and camped on the morning of July 4 near the head of the northern arm of Buchanan Bay. Hardly was the tent set up when a bear was seen out in the bay, and we immediately went in pursuit, and in a short time had him killed. He proved to be a fine large specimen. While after the bear I noticed a herd of musk oxen a few miles up the valley, and after the bear had been brought into camp and skinned, and we had snatched a few hours' sleep, we went after the musk oxen. Eight of these were secured, including two fine bulls and two live calves, the latter following us back to camp of their own accord. The next three days were occupied in getting the beef to camp. I then crossed to the southern arm of Buchanan Bay, securing another musk ox. Returning to Princess Marie Bay, I camped on the morning of the 14th at the glacier which fills the head of Sawyer Bay.

During the following six days I ascended the glacier, crossed the ice cap to its western side, and from elevations of from 4,000 to 4,700 feet looked down upon the snow-free western side of Ellesmere Land, and out into an ice-free fjord, extending some 50 miles to the northwest. The season here was at least a month earlier than on the east side, and the general appearance of the country reminded me of the Whale Sound region of Greenland. Clear weather for part of one day enabled me to take a series of angles, then fog and rain and snow settled down upon us. Through this I steered by compass back to and down the glacier, camping on the 21st in my camp of the 15th. The return from here to the ship was somewhat arduous, owing to the rotten condition of the one-year ice and the deep pools and canals of water on the surface of the old floes. These presented the alternative of making endless detours or wading through water often waist deep. During seven days our clothing, tent, sleeping gear, and food were constantly saturated. The *Windward* was reached on the 28th of July.

In spite of the discomforts and hardships of this trip, incident to the lateness of the season, I felt repaid by its results. In addition to completing the notes requisite for a chart of the Princess Marie-Buchanan Bay region, I had been fortunate in crossing the Ellesmere Land ice cap and looking upon the western coast. The game secured during this trip comprised a polar bear, 7 musk oxen, 3 oogsook, and 14 seals.

When I returned to the *Windward* she was round in the eastern side of Franklin Pierce Bay. A party had left two days before with dogs, sledge, and boat, in an attempt to meet me and supply me with provisions. Three days were occupied in communicating with them and getting them and their outfit on board. The *Windward* then moved back to her winter berth at Cape D'Urville, took the dogs on board, and on the morning of Wednesay, August 2, got under way.

During the next five days we advanced some 12 miles, when a southerly wind jammed the ice on us and drifted us north abreast of the starting point. Early Tuesday morning, the 8th, we got another start, and the ice gradually slackening, we kept under way, reached open water a little south of Cape Albert, and arrived at Cape Sabine at 10 p. m.

At Cape Sabine I landed a cache and then steamed over to Etah, arriving at 5 a. m. of the 9th. Here we found mail, and learned that the steamship *Diana*, which the club had sent up to communicate with me, was out after walrus. Saturday morning the *Diana* returned, and I had the great pleasure of taking Secretary Bridgman, commanding the club's expedition, by the hand.

Though the year had not been marked by any startling results, it was a year of hard and continuous work for the entire party. During the year I obtained the material for an authentic map of the Buchanan Bay,

Bache Peninsula, Princess Marie Bay region; crossed the Ellesmere Land ice cap to the west side of that land; established a continuous line of caches from Cape Sabine to Fort Conger, containing some 14 tons of supplies; rescued the original records and private papers of the Greely expedition; fitted Fort Conger as a base for future work, and familiarized myself and party with the entire region as far north as Cape Beechy.

With the exception of the supplies at Cape D'Urville, all the provisions, together with the current supplies and dog food (the latter an excessive item), had been transported by sledge.

Finally, discouraging as was the accident to my feet, I was satisfied, since my effort to reach the northwest coast of Greenland from Conger in May, that the season was one of extremely unfavorable ice condition north of Cape Beechy, and doubt, even if the accident had not occurred, whether I should have found it advisable, on reaching Cape Hecla, to attempt the last stage of the journey.

My decision not to attempt to winter at Fort Conger was arrived at after careful consideration. Two things controlled this decision: First, the uncertainty of carrying dogs through the winter, and, second, the comparative facility with which the distance from Etah to Fort Conger can be covered with light sledges.

After the rendezvous with the *Diana*, I went on board the latter ship and visited all the native settlements, gathering skins and material for clothing and sledge equipment and recruiting my dog teams. The *Windward* was sent hunting walrus during my absence. The *Diana* also assisted in this work.

August 25.—The *Windward* sailed for home, followed on the 28th by the *Diana*, after landing me with my party, equipment, and additional supplies at Etah.

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The *Diana* seemed to have gathered in and taken with her all the fine weather, leaving us a sequence of clouds, wind, fog, and snow, which continued with scarcely a break for weeks.

After her departure the work before me presented itself in its own natural sequence as follows: Protect the provisions, construct our winter quarters, then begin building sledges and grinding walrus meat for dog pemmican for the spring campaign.

During the first month a number of walrus were killed from our boats off the mouth of the fjord; then the usual Arctic winter settled down upon us, its monotony varied only by the visits of the natives, occasional deer hunts, and a December sledge journey to the Eskimo settlements in Whale Sound as far as Kangerd-looksoah. In this nine-days' trip some 240 miles were covered in six marches, the first and the last marches being 60 to 70 miles. I returned to Etah just in time

to escape a severe snowstorm, which stopped communication between Etah and the other Eskimo settlements completely until I sent a party with snowshoes and a specially constructed sledge, carrying no load, and manned by double teams of dogs, to break the trail.

During my absence some of my natives had crossed to Mr. Stein's place at Sabine, and January 9 I began the season's work by starting a few sledge loads of dog food for Cape Sabine, for use of my teams in the spring journey. From this time on, as the open water in Smith Sound permitted, more dog food was sent to Sabine, and as the light gradually increased, some of my Eskimos were kept constantly at Sonntag Bay, some 20 miles to the south, on the lookout for walrus.

My general programme for the spring work was to send three divisions of sledges north as far as Conger, the first to be in charge of Henson, while I brought up the rear with the third.

From Conger I should send back a number of Eskimos, retain some at Conger, and with others proceed north from there either via Hecla or the north point of Greenland, as circumstances might determine.

I wanted to start the first division on the 15th of February, the second a week later, and leave with the third March 1, but a severe storm, breaking up the ice between Etah and Littleton Island, delayed the departure of the first division of seven sledges until the 19th.

The second division of six sledges started on the 26th, and March 4 I left with the rear division of nine sledges. Three marches carried us to Cape Sabine, along the curving northern edge of the north water. Here a northerly gale with heavy drift detained me for two days. Three more marches in a temperature of −40° F. brought me to the house at Cape D'Urville. Records here informed me that the first division had been detained here a week by stormy weather, and the second division had left but two days before my arrival. I had scarcely arrived when two of Henson's Eskimos came in from Richardson Bay, where one of them had severely injured his leg by falling under a sledge. One day was spent at the D'Urville house drying our clothing, and on the 13th I got away on the trail of the other divisions with seven sledges, the injured man going to Sabine with the supporting party.

I hoped to reach Cape Louis Napoleon on this march, but the going was too heavy and I was obliged to camp in Dobbin Bay, about 5 miles short of the cape.

The next day I hoped on starting to reach Cape Fraser, but was again disappointed, a severe windstorm compelling me to halt a little south of Hayes Point, and hurriedly build snow igloos in the midst of a blinding drift.

All that night and the next day and the next night the storm continued. An early start was made on the 16th, and in calm but very thick weather we pushed on to Cape Fraser. Here we encountered

the wind and drift full in our faces and violent, making our progress from here to Cape Norton Shaw along the ice-foot very trying.

The going from here across Scoresby and Richardson bays was not worse than the year before; and from Cape Wilkes to Cape Lawrence the same as we had always found it. These two marches were made in clear but bitterly windy weather.

Another severe southerly gale held us prisoners at Cape Lawrence for a day. The 20th was an equally cruel day, with wind still savage in its strength, but the question of food for my dogs gave me no choice but to try to advance. At the end of four hours we were forced to burrow into a snow bank for shelter, where we remained till the next morning.

In three more marches we reached Cape von Buch. Two more days of good weather brought us to a point a few miles north of Cape Defosse. Here we were stopped by another furious gale with drifting snow, which prisoned us for two nights and a day.

The wind was still bitter in our faces when we again got underway the morning of the 27th. The ice-foot became worse and worse up to Cape Cracroft, where we were forced down into the narrow tidal joint at the base of the ice-foot; this path was a very narrow and tortuous one, frequently interrupted, and was extremely trying on men and sledges. Cape Lieber was reached on this march. At this camp the wind blew savagely all night, and in the morning I waited for it to moderate before attempting to cross Lady Franklin Bay.

While thus waiting, the returning Eskimos of the first and second divisions came in. They brought the very welcome news of the killing of 21 musk oxen close to Conger. They also reported the wind out in the bay as less severe than at the cape.

I immediately got underway and reached Conger just before midnight of the 28th, twenty-four days from Etah, during six of which I was held up by storms.

The first division had arrived four days and the second two days earlier. During this journey there had been the usual annoying delays of broken sledges, and I had lost numbers of dogs.

The process of breaking in the tendons and muscles of my feet to their new relations, and the callousing of the amputation scars, in this, the first serious demand upon them, had been disagreeable, but was, I believed, final and complete. I felt that I had no reason to complain.

The herd of musk oxen so opportunely secured near the station, with the meat cached here the previous spring, furnished the means to feed and rest my dogs. A period of thick weather followed my arrival at Conger, and not until April 2 could I send back the Eskimos of my division.

On leaving Etah I had not decided whether I should go north from Conger via Cape Hecla, or take the route along the northwest coast of

Greenland. Now I decided upon the latter. The lateness of the season and the condition of my dogs might militate against a very long journey, and if I chose the Hecla route and failed of my utmost aims the result would be complete failure. If, on the other hand, I chose the Greenland route and found it impossible to proceed northward over the pack, I still had an unknown coast to exploit, and the opportunity of doing valuable work. Later developments showed my decision to be a fortunate one.

I planned to start from Conger the 9th of April, but stormy weather delayed the departure until the 11th, when I got away with seven sledges.

At the first camp beyond Conger my best Eskimo was taken sick, and the following day I brought him back to Conger, leaving the rest of the party to cross the channel to the Greenland side, where I would overtake them. This I did two or three days later, and we began our journey up the northwest Greenland coast. As far as Cape Sumner we had almost continuous road making through very rough ice. Before reaching Cape Sumner we could see a dark water sky, lying beyond Cape Brevoort, and knew that we should find open water there.

From Cape Sumner to Polaris Boat Camp, in Newman Bay, we cut a continuous road. Here we were stalled until the 21st by continued and severe winds. Getting started again in the tail end of the storm, we advanced as far as the open water, a few miles east of Cape Brevoort, and camped. This open water, about 3 miles wide at the Greenland end, extended clear across the mouth of Robeson Channel to the Grinnell Land coast, where it reached from Lincoln Bay to Cape Rawson. Beyond it to the north and northwest as far as could be seen were numerous lanes and pools. The next day was devoted to hewing a trail along the ice foot to Repulse Harbor, and on the 23d, in a violent gale accompanied by drift, I pushed on to the "Drift Point" of Beaumont (and later Lockwood), a short distance west of Black Horn Cliffs.

The ice foot as far as Repulse Harbor, in spite of the road making of the previous day, was very trying to sledges, dogs, and men. The slippery side slopes, steep ascents, and precipitous descents wrenched and strained the latter, and capsized, broke, and ripped shoes from the former.

I was not surprised to see from the "Drift Point" igloo that the Black Horn Cliffs were fronted by open water. The pack was in motion here, and had only recently been crushing against the ice foot, where we built our igloo. I thought I had broken my feet in pretty thoroughly on my journey from Etah to Conger, but this day's work of handling a sledge along the ice-foot made me think they had never encountered any serious work before. A blinding snowstorm on the 24th kept us inactive. The next day I made a reconnoissance to the cliffs, and the next day set the entire party to work hewing a road along the ice foot.

That night the temperature fell to −25° F., forming a film of young ice upon the water. The next day I moved up close to the cliffs, and then with three Eskimos reconnoitered the young ice. I found that by proceeding with extreme care it would in most places support a man.

With experienced Ahsayoo ahead constantly testing the ice with his seal spear, myself next, and two Eskimos following, all with feet wide apart, and sliding instead of walking, we crept past the cliffs. Returning we brushed the thin film of newly fallen snow off the ice with our feet for a width of some 4 feet, to give the cold free access to it.

I quote from my diary for the 27th:

> At last we are past the barrier, which has been looming before me for the last ten days, the open water at the Black Horn Cliffs. Sent two of my men, whose nerves are disturbed by the prospect ahead, back to Conger. This leaves me with Henson and three Eskimos. My supplies can now be carried on the remaining sledges. Still further stiffened by the continuous low temperature of the previous night, the main sheet of new ice in front of the cliffs was not hazardous as long as the sledges kept a few hundred feet apart, did not stop, and their drivers kept some yards away to one side. Beyond the limit of my previous day's reconnoissance there were areas of much younger ice, which caused me considerable apprehension, as it buckled to a very disquieting extent beneath dogs and sledges, and from the motion of the outside pack was crushed up in places while narrow cracks opened up in others. Finally, to my relief, we reached the ice-foot beyond the cliffs and camped.

The next day there was a continuous lane of water 100 feet wide along the ice foot by our camp, and the space in front of the cliffs was again open water. We crossed just in time.

Up to Cape Stanton we had to hew a continuous road along the ice-foot. After this the going was much better to Cape Bryant. Off this section of the coast the pack was in constant motion, and an almost continuous lane of water extended along the ice foot. A little west of Cape Bryant I killed 2 musk oxen, the flesh of which my dogs highly appreciated. A long search at Cape Bryant finally discoverd the remains of Lockwood's cache and cairn, which had been scattered by bears. At 3.30 p. m. the 1st of May I left Cape Bryant to cross the wide indentation lying between Cape Bryant and Cape Britannia. Three marches, mostly in thick weather and over alternating hummocky blue ice and areas of deep snow, brought us at 1 a. m. of the 4th to Cape North (the northern point of Cape Britannia Island). From this camp, after a sleep, I sent back 2 more Eskimos and the 12 poorest dogs, leaving Henson, 1 Eskimo, and myself with 3 sledges and 16 dogs for the permanent advance party.

From Cape North, a ribbon of young ice, on the so-called tidal crack which extends along this coast, gave us a good lift nearly across Nordenskjöld Inlet. Then it became unsafe, and we climbed a heavy rubble barrier to the old floe ice inside, which we followed to Cape Benet and camped. Here we were treated to another snowstorm.

Another strip of young ice gave us a passage nearly across Mascart Inlet until, under Cape Payer, I found it so broken up that two of the sledges and nearly all of the dogs got into the water before we could escape from it. Then a pocket of snow, thigh and waist deep, over rubble ice under the lee of the cape stalled us completely. I pitched the tent, fastened the dogs, and we devoted the rest of the day to stamping a road through the snow with our snowshoes. Even then, when we started the next day, I was obliged to put two teams to one sledge in order to move it.

Cape Payer was a hard proposition. The first half of the distance round it we were obliged to cut a road, and on the last half, with 12 dogs and 3 men to each sledge to push and pull them, snow-plow fashion, through the deep snow.

Distant Cape was almost equally inhospitable, and it was only after long and careful reconnoissance that we were able to get our sledges past along the narrow crest of the huge ridge of ice forced up against the rocks. After this we had comparatively fair going on past Cape Ramsay, Dome Cape, and across Meigs Fiord as far as Mary Murray Island. Then came some heavy going, and at 11.40 p. m. of May 8 we reached Lockwood's cairn on the north end of Lockwood Island. From this cairn I took the record and thermometer deposited there by Lockwood eighteen years before. The record was in a perfect state of preservation.

One march from here carried us to Cape Washington. Just at midnight we reached the low point, which is visible from Lockwood Island, and great was my relief to see, on rounding this point, another splendid headland, with two magnificent glaciers debouching near it, rising across an intervening inlet. I knew now that Cape Washington was not the northern point of Greenland, as I had feared. It would have been a great disappointment to me, after coming so far, to find that another's eyes had forestalled mine in looking first upon the coveted northern point.

Nearly all my hours for sleep at this camp were taken up by observations and a round of angles. The ice north from Cape Washington was in a frightful condition, utterly impracticable. Leaving Cape Washington, we crossed the mouth of the fiord, packed with blue-top floe bergs, to the western edge of one of the big glaciers, and then over the extremity of the glacier itself, camping near the edge of the second. Here I found myself in the midst of the birthplace of the "floe bergs," which could be seen in all the various stages of formation. These floe bergs are merely degraded icebergs—that is, bergs of low altitude, detached from the extremity of a glacier, which has for some distance been forcing its way along a comparatively level and shallow sea bottom.

FIG. 1. ETAH, WINTER QUARTERS, 1899-1900.

FIG. 2.—LATERAL RIVER OF BENEDICT GLACIER.

FIG. 1.—MUSK OXEN NEAR CAPE JESUP.

FIG. 2.—MUSK OXEN, BUCHANAN BAY.

From this camp we crossed the second glacier, then a small fiord, where our eyes were gladdened by the sight of a polar bear, which a couple of bullets from my carbine quickly transformed into dog meat for my faithful teams. The skin of this bear I have brought back as a trophy for the club.

It was evident to me now that we were very near the northern extremity of the land, and when we came within view of the next point ahead, I felt that my eyes rested at last upon the Arctic Ultima Thule (Cape Morris Jesup). The land ahead also impressed me at once as showing the characteristics of a musk-ox country.

This point was reached in the next march, and I stopped to take variation and latitude sights. Here my Eskimo shot a hare, and we saw a wolf track and traces of musk oxen. A careful reconnoissance of the pack to the northward, with glasses, from an elevation of a few hundred feet, showed the ice to be of a less impracticable character than it was north of Cape Washington. What were evidently water clouds showed very distinctly on the horizon. This water sky had been apparent ever since we left Cape Washington, and at one time assumed such a shape that I was almost deceived into taking it for land. Continued careful observation destroyed the illusion. My obversations completed, we started northward over the pack, and camped a few miles from land.

The two following marches were made in a thick fog, through which we groped our way northward over broken ice and across gigantic, wave-like drifts of hard snow. One more march in clear weather over frightful going, consisting of fragments of old floes, ridges of heavy ice thrown up to heights of 25 to 50 feet, crevasses and holes masked by snow, the whole intersected by narrow leads of open water, brought us at 5 a. m., on the 16th, to the northern edge of a fragment of an old floe bounded by water. A reconnoissance from the summit of a pinnacle of the floe, some 50 feet high, showed that we were on the edge of the disintegrated pack, with a dense water sky not far distant.

My hours for sleep at this camp were occupied in observations, and making a transit profile of the northern coast from Cape Washington eastward.

The next day I started back for the land, and having a trail to follow, and no time wasted in reconnoissance, reached it in one long march, and camped.

Leaving this camp on the 18th, as we were traveling eastward on the ice foot an hour later, I saw a herd of 6 musk oxen in one of the coast valleys, and in a short time had secured them. Skinning and cutting up these animals and feeding the dogs to repletion consumed some hours, and we then resumed our march, getting an unsuccessful shot at a passing wolf as we went.

Within a mile of our next camp a herd of 15 musk oxen lay fast asleep; I left them undisturbed. From here on, for three marches, we reeled off splendid distances over good going, in blinding sunshine, and in the face of a wind from the east which burned our faces like a sirocco.

The first march took us to a magnificent cape (Cape Bridgman), at which the northern face of the land trends away to the southeast. This cape is in the same latitude as Cape Washington. The next two carried us down the east coast to the eighty-third parallel. In the first of these we crossed the mouth of a large fjord penetrating for a long distance in a southwesterly (true) direction. On the next, in a fleeting glimpse through the fog, I saw a magnificent mountain of peculiar contour which I recognized as the peak seen by me in 1895 from the summit of the interior ice cap south of Independence Bay, rising proudly above the land to the north. This mountain was then named by me Mount Wistar. Finally, the density of the fog compelled a halt on the extremity of a low point, composed entirely of fine glacial drift, and which I judged to be a small island in the mouth of a large fjord.

From my camp of the previous night I had observed this island (?) and beyond and over it a massive block of a mountain, forming the opposite cape of a large intervening fjord, and beyond that again another distant cape. Open water was clearly visible a few miles off the coast, while, not far out, dark water clouds reached away to the southeast.

At this camp I remained two nights and a day, waiting for the fog to lift. Then, as there seemed to be no indications of its doing so, and my provisions were exhausted, I started on my return journey at 3.30 a. m. on the 22d of May, after erecting a cairn, in which I deposited the following record:

COPY OF RECORD IN CAIRN AT CLARENCE WYCKOFF ISLAND.

Arrived here at 10.30 p. m. May 20, from Etah via Fort Conger and north end of Greenland. Left Etah March 4. Left Conger April 15. Arrived north end of Greenland May 13. Reached point on sea ice latitude 83° 50′ north May 16.

On arrival here had rations for one more march southward. Two days dense fog have held me here. Am now starting back.

With me are my man, Mathew Henson; Ahngmalokto, an Eskimo; 16 dogs, and 3 sledges.

This journey has been made under the auspices of, and with the funds furnished by, the Peary Arctic Club of New York City.

The membership of this club comprises Morris K. Jesup, Henry W. Cannon, Herbert L. Bridgman, John H. Flagler, E. C. Benedict, James J. Hill, H. H. Benedict, Fredk. E. Hyde, E. W. Bliss, H. H. Sands, J. M. Constable, C. F. Wyckoff, E. G. Wyckoff, Chas. P. Daly, Henry Parish, A. A. Raven, G. B. Schley, E. B. Thomas, and others.

(Signed) R. E. PEARY,
Civil Engineer, U. S. N.

The fog kept company with us on our return almost continuously until we had passed Lockwood Island, but, as we had a trail to follow, did not delay us so much as the several inches of heavy snow that fell in a furious arctic blizzard, which came rushing in from the polar basin and imprisoned us for two days at Cape Bridgman.

At Cape Morris K. Jesup, the northern extremity, I erected a prominent cairn, in which I deposited the following record:

COPY OF RECORD IN NORTH CAIRN.

May 13, 1900—5 a. m.—Have just reached here from Etah via Fort Conger. Left Etah March 4. Left Conger April 15. Have with me my man, Henson; an Eskimo, Ahngmalokto; 16 dogs, and 3 sledges; all in fair condition. Proceed to-day due north (true) over sea ice. Fine weather. I am doing this work under the auspices of, and with funds furnished by, the Peary Arctic Club of New York City.

The membership of this club comprises Morris K. Jesup, Henry W. Cannon, Herbert L. Bridgman, John H. Flagler, E. C. Benedict, Fredk. E. Hyde, E. W. Bliss, H. H. Sands, J. M. Constable, C. F. Wyckoff, E. G. Wyckoff, Chas. P. Daly, Henry Parish, A. A. Raven, E. B. Thomas, and others.

(Signed) R. E. PEARY,
Civil Engineer, U. S. N.

May 17.—"Have returned to this point. Reached 83° 50′ north latitude due north of here. Stopped by extremely rough ice intersected by water cracks. Water sky to north. Am now going east along the coast. Fine weather."

May 26.—"Have again returned to this place. Reached point on east coast about north latitude 83°. Open water all along the coast a few miles off. No land seen to north or east. Last seven days continuous fogs, wind, and snow. Is now snowing, with strong westerly wind. Temperature 20° F. Ten musk oxen killed east of here. Expect to start for Conger to-morrow."

At Cape Washington, also, I placed a copy of Lockwood's record, from the cairn at Lockwood Island, with the following indorsement:

This copy of the record left by Lieut. J. B. Lockwood and Sergt. (now colonel) D. L. Brainard, U. S. Army, in the cairn on Lockwood Island, southwest of here, May 16, 1882, is to-day placed by me in this cairn on the farthest land seen by them, as a tribute to two brave men, one of whom gave his life for his Arctic work.

May 29.—For a few minutes on one of the marches the fog lifted, giving us a magnificent panorama of the north coast mountains. Very somber and savage they looked, towering white as marble with the newly fallen snow, under their low threatening canopy of lead-colored clouds. Two herds of musk oxen were passed—one of 15 and one of 18—and two or three stragglers. Four of these were shot for dog food, and the skin of one, killed within less than a mile of the extreme northern point, has been brought back as a trophy for the club.

Once free of the fog off Mary Murray Island we made rapid progress, reaching Cape North in four marches from Cape Washington.

Clear weather showed us the existence of open water a few miles off the shore, extending from Dome Cape to Cape Washington. At Black Cape there was a large open water reaching from the shore northward. Everywhere along this coast I was impressed by the startling evidences of the violence of the blizzard of a few days before. The polar pack had been driven resistlessly in against the iron coast, and at every projecting point had risen to the crest of the ridge of old ice, along the outer edge of the ice foot in a terrific cataract of huge blocks. In places these mountains of shattered ice were 100 feet or more in height. The old ice in the bays and fjords had had its outer edge loaded with a great ridge of ice fragments, and was itself cracked and crumpled into huge swells by the resistless pressure. All the young ice which had helped us on our outward passage had been crushed into countless fragments, and swallowed up in the general chaos.

Though hampered by fog, the passage from Cape North to Cape Bryant was made in twenty-five and a half marching hours. At 7 a. m. of the 6th of June, we camped on the end of the ice foot, at the eastern end of Black Horn Cliffs. A point a few hundred feet up the bluffs commanding the region in front of the cliffs showed it to be filled by small pieces of old ice held in place against the shore by pressure of the outside pack. It promised at best the heaviest kind of work, with the certainty that it would run abroad at the first release of pressure.

The next day, when about one-third the way across, the ice did begin to open out, and it was only after a rapid and hazardous dash from cake to cake that we reached an old floe, which after several hours of heavy work allowed us to climb upon the ice-foot of the western end of the cliffs.

From here on rapid progress was made again, three more marches taking us to Conger, where we arrived at 1.30 a. m. June 10, though the open water between Repulse Harbor and Cape Brevoort, which had now expanded down Robeson Channel to a point below Cape Sumner and the rotten ice under Cape Sumner hampered us seriously. In passing I took copies of the Beaumont English records from the cairn at Repulse Harbor, and brought them back for the archives of the club. They form one of the finest chapters of the most splendid courage, fortitude, and endurance, under dire stress of circumstances, that is to be found in the history of Arctic explorations.

In this journey I had determined conclusively the northern limit of the Greenland Archipelago or land group, and had practically connected the coast southward to Independence Bay, leaving only that comparatively short portion of the periphery of Greenland lying between Independence Bay and Cape Bismarck indeterminate. The nonexistence of land for a very considerable distance to the northward

and northeastward was also settled, with every indication pointing to the belief that the coast along which we traveled formed the shore of an uninterrupted central polar sea, extending to the Pole, and beyond to the Spitzbergen and Franz Josef Land groups of the opposite hemisphere.

The origin of the floe bergs and palæocrystic ice was definitely determined. Further than this, the result of the journey was to eliminate this route as a desirable or practicable one by which to reach the Pole. The broken character of the ice, the large amount of open water, and the comparatively rapid motion of the ice, as it swung round the northern coast into the southerly setting East Greenland current, were very unfavorable features.

During my absence some 33 musk oxen and 10 seals had been secured in the vicinity of Conger; caches for my return had been established at Thank God Harbor, Cape Lieber, and Lincoln Bay, and sugar, milk, and tea had been brought up from the various caches between Conger and Cape Louis Napoleon.

July was passed by a portion of the party in the region from Discovery Harbor westward via Black Rock Vale and Lake Hazen, where some 40 musk oxen were secured.

During August and early September various other hunting trips of shorter duration were made, resulting in the killing of some 20 musk oxen.

1900–1901.

The middle of September I started with Henson and 4 Eskimos to Lake Hazen to secure musk oxen for our winter supply, it being evident that my ship would not reach us. Going west as far as the valley of the Very River, by October 4, 92 musk oxen had been killed. Later 9 more were secured, making a total of 101 for the autumn hunting.

From the beginning of November to March 6, the greater portion of the time was passed by my party in igloos built in the vicinity of the game killed in various localities from Discovery Harbor to Ruggles River.

April 5.—I left Conger with Henson, 1 Eskimo, 2 sledges, and 12 dogs for my northern trip. At the same time the remainder of the party, with 2 sledges and 7 dogs and pups, started south for Capes D'Urville and Sabine to communicate with or obtain tidings of my ship. On reaching Lincoln Bay, it was evident to me that the condition of men and dogs was such as to negative the possibility of reaching the pole, and I reluctantly turned back.

Arriving at Conger, after an absence of eight days, I found the remainder of my party there. They had returned to Conger after an absence of four days, having proceeded one-third of the distance across Lady Franklin Bay.

Fortunately, the night before I arrived, one of the Eskimos secured several musk oxen above St. Patricks Bay, which enabled me to feed my dogs before starting south, which I did with the entire party on April 17.

April 30.—At Hayes Point I met the party from the *Windward* attempting to reach Conger, and received my mail, learning that the *Windward* was at Payer Harbor with Mrs. Peary and our little girl on board. After a rest at the D'Urville box house, I went on to the *Windward*, arriving May 6.

After a few days' rest the work of establishing new caches along the coast northward toward Conger was commenced, and continued until the middle of June.

Then the preparing of Payer Harbor for winter quarters was carried on till July 3, when the *Windward* broke out of the ice and steamed over to the Greenland side.

July was devoted to killing walrus, and 128 were secured and transported to Payer Harbor.

August 4.—The *Erik*, sent up by the club in command of Secretary H. L. Bridgman to communicate with me, arrived at Etah.

The usual tour of visits to the Eskimo settlements was then made, and both ships pressed into the work of hunting walrus until August 24, when the *Windward* proceeded southward, and the *Erik* steamed away to land me and my party and the catch of walrus at Payer Harbor.

A large quantity of heavy ice blocking the way to Payer Harbor, I requested Secretary Bridgman to land me and my party and walrus meat in a small bight, some 12 or 15 miles south of Cape Sabine, from whence I could proceed to Payer Harbor in my boats or sledges when opportunity offered. This was done, and on the 29th of August the *Erik* steamed away.

1901–2.

On the 16th of September I succeeded in reaching Payer Harbor, crossing Rosse Bay partly by sledge and partly by boat, and going overland across Bedford Pim Island.

Soon after this my Eskimos began to sicken, and by November 19, 6 of them were dead.

During this time I personally sledged much of the material from Erik Harbor to headquarters, and Henson went to the head of Buchanan Bay with some of the Eskimos and secured 10 musk oxen.

The winter passed quietly and comfortably. Two more musk oxen were secured in Buchanan Bay, and 6 deer at Etah.

January 2.—Work was begun in earnest on preparations for the spring campaign, which opened on the 11th of February. On this day I sent off 6 sledges, with light loads, to select a road across the

FIG. 1.—ICE JAM AT CAPE JOHN BARROW.

FIG. 2.—ALONG THE ICE FOOT.

FIG. 1.—CAPE ALBERT.

FIG. 2.—CROSSING PRINCESS MARIE BAY.

mouth of Buchanan Bay, and build an igloo abreast of Cape Albert. On the 12th I sent two of my best hunters on a flying reconnoissance and bear hunt in the direction of Cape Louis Napoleon.

On the 13th 8 sledges went out, taking dog food nearly to Cape D'Urville. On the 16th my two scouts returned with a favorable report, and on the 18th 10 sledges went out loaded with dog food to be taken to Cape Louis Napoleon. This party returned on the 22d.

On the evening of the 28th everything was in readiness for Henson to start the next day, it being my intention to send him on ahead with three picked men and light loads to pioneer the way to Conger, I to follow a few days later with the main party.

A northerly gale delayed his departure until the morning of March 3, when he got away with 6 sledges and some 50 dogs. Two of these sledges were to act as a supporting party as far as Cape Lawrence.

At 9 a. m. of March 6, 14 sledges trailed out of Payer Harbor and rounded Cape Sabine for the northern journey, and at noon I followed them with my big sledge, the "Long Serpent," drawn by a team of 10 fine grays. Two more sledges accompanied me. The temperature at the time was $-20°$ F. The minimum of the previous night had been $-38°$ F.

We joined the others at the igloos abreast of Cape Albert, and camped there for the night. Temperature $-43°$ F.

The next day we made Cape D'Urville in temperature from $-45°$ to $-49°$ F.

Here I stopped a day to dry our foot gear thoroughly, and left on the morning of the 9th with some supplies from the box house. Two sledges returned from here. Camped about 5 miles from Cape Louis Napoleon. The next march carried me to Cape Fraser, and the next to Cape Collinson. During this march, for the first time in the four seasons that I have been over this route, I was able to take a nearly direct course across the mouth of Scoresby Bay, instead of making a long detour into it.

One march from Cape Collinson carried me to Cape Lawrence, on the north side of Rawlings Bay.

The crossing of this bay, though more direct than usual, was over extremely rough ice. Learning from Henson's letter at Cape Lawrence that I had gained a day on him, and not wanting to overtake him before reaching Conger, I remained here a day, repairing several sledges which had been damaged in the last march. Five men, with the worst sledges and poorest dogs, returned from here.

Three more marches took us to Cape von Buch, on the north side of Carl Ritter Bay, temperature ranging from $-35°$ to $-45°$ F. Heavy going in many places.

Two more marches carried us to the first coast valley north of Cape Defosse. I had now gained two days on the advance party.

The character of the channel ice being such that we were able to avoid the terrible ice foot which extends from here to Cape Lieber, and my dogs being still in good condition, I made a spurt from here and covered the distance to Conger in one march, arriving about an hour and a half after Henson and his party.

I had covered the distance from Payer Harbor to Conger, some 300 miles, in twelve marches.

Four days were spent at Conger overhauling sledges and harness, drying and repairing clothing, and scouting the country, as far as The Bellows, in search of musk oxen. None were seen, but about 100 hares were secured in the four days. Temperature during this time from $-40°$ to $-57°$ F. Seven Eskimos returned from here, taking with them the instruments of the Lady Franklin Bay Expedition and other items of Government property abandoned here in 1883.

On the morning of the 24th I started north with nine sledges. We camped the first night at "Depot B." The next march I had counted on making Lincoln Bay, but just before reaching Wrangell Bay a sudden, furious gale, with blinding drift, drove us into camp at the south point of the bay. Here we were storm bound during the 26th, but got away on the morning of the 27th and pushed on to Cape Union, encountering along this portion of the coast the steep side slopes of hard snow, which are so trying to men and sledges and dogs.

Open water, the clouds over which we saw from Wrangell Bay Camp, was about 100 yards beyond our igloo, and extended from there, as I judged, northward beyond Cape Rawson, and reached entirely across the channel to the Greenland coast at Cape Brevoort, as in 1900.

Fortunately, with the exercise of utmost care, and at the expense of a few narrow escapes and incessant hard work, we were able to work our sledges along the narrow and villainous ice-foot to and around Black Cape.

The ice foot along this section of the coast was the same as was found here by Egerton and Rawson in 1876 and Pavy in 1882, necessitating the hewing of an almost continuous road; but a party of willing, light-hearted Eskimos makes comparatively easy work of what would be a slow and heart-breaking job for two or three white men. Beyond Black Cape the ice foot improved in character, and I pushed along to camp at the *Alert's* winter quarters. Simultaneously with seeing the *Alert's* cairn three musk oxen were seen a short distance inland, which I went away after and secured. The animals were very thin, and furnished but a scant meal for my dogs.

One march from here carried us to Cape Richardson, and the next under the lee of View Point, where we were stopped, and driven to build our igloo with all possible speed, by one of the common arctic gales. There were young ice, pools of water, and a nearly continuous water sky all along the shore.

As the last march had been through deep snow, I did not dare to attempt the English short cut across Fielden Peninsula behind Cape Joseph Henry, preferring to take the ice-foot route round it.

For a short distance this was the worst bit of ice foot I have ever encountered. By the slipping of my sledge two men nearly lost their lives, saving themselves by a most fortuitous chance, with their feet already dangling over the crest of a vertical face of ice some 50 feet in height.

At the very extremity of the cape we were forced to pass our sledges along a shelf of ice less than 3 feet in width, glued against the face of the cliff at an elevation which I estimated at the time as 75 feet above the ragged surface of the floe beneath.

On the western side of the cape the ice foot broadened and became nearly level, but was smothered in such a depth of light snow that it stalled us and we went into camp. The next day we made Crozier Island.

During April 2 and 3 we were held here by a westerly storm, and the 4th and 5th were devoted to hunting musk oxen, of which 3 were secured, 2 of them being very small.

From here I sent back 3 Eskimos, keeping Henson and 4 Eskimos with me.

During this time reconnoissances of the polar pack northward were made with the glasses from the summit of the island and from Cape Hecla. The pack was very rough, but apparently not as bad as that which I saw north of Cape Washington two years before. Though unquestionably a hard proposition, it yet looked as though we might make some progress through it, unless the snow was too deep and soft. This was a detail which the glasses could not determine.

On the morning of April 6 I left Crozier Island, and a few hours later, at the point of Cape Hecla, we swung our sledges sharply to the right, and climbed over and down the parapet of the ice foot onto the polar pack. As the sledges plunged down from the ice foot their noses were buried out of sight, the dogs wallowed belly deep in the snow, and we began our struggle due northward.

We had been in the field now just a month. We had covered not less than 400 miles of the most arduous traveling in temperatures of from $-35°$ to $-57°$ F., and we were just beginning our work—i. e., the conquest of the polar pack, the toughest proposition in the whole wide expanse of the arctic region.

Some two miles from the cape was a belt of very recent young ice, running parallel with the general trend of the coast. Areas of rough ice caught in this compelled us to exaggerated zigzags, and doubling on our track. It was easier to go a mile around on the young ice than to force the sledge across one of these islands. The northern edge of the new ice was a high wall of heavily rubbled old ice, through which,

after some reconnoissance, we found a passage to an old floe, where I gave the order to build an igloo. We were now about 5 miles from the land.

The morning of the 7th brought us fine weather. Crossing the old floe we came upon a zone of old floe fragments, deeply blanketed with snow. Through the irregularities of this we struggled, the dogs floundering almost useless, occasionally one disappearing for a moment, now treading down the snow around a sledge to dig it out of a hole into which it had sunk, now lifting the sledges bodily over a barrier of blocks, veering right and left, doubling in our track, road making with snowshoe and pickax. Late in the day a narrow ditch gave us a lift for a short distance, then one or two little patches of level going, then two or three small old floes, which though deep with snow, seemed like a godsend compared with the wrenching work earlier. Camped in the lee of a large hummock on the northern edge of a small but very heavy old floe. Everyone thoroughly tired, and the dogs utterly lifeless, dropping motionless in the snow as soon as the whip stopped.

We were now due north of Hecla, and I estimated we had made some 6 miles, perhaps 7, perhaps only 5. A day of work like this makes it difficult to estimate distances. This is a fair sample of our day's work.

On the 12th we were storm bound by a gale from the west, which hid even those dogs fastened nearest to the igloo. During our stay here the old floe on which we were camped split in two with a loud report, and the ice cracked and rumbled and roared at frequent intervals.

In the first march beyond this igloo we were deflected westward by a lead of practically open water, the thin film of young ice covering it being unsafe even for a dog. A little farther on a wide canal of open water deflected us constantly to the northwest and then west, until an area of extremely rough ice prevented us from following it farther. Viewed from the top of a high pinnacle this area extended west and northwest on both sides of the canal, as far as could be seen. I could only camp and wait for this canal, which evidently had been widened (though not newly formed) by the storm of the day before, to close up or freeze over. During our first sleep at this camp there was a slight motion of the lead, but not enough to make it practicable. From here I sent back two more Eskimos.

Late in the afternoon of the 14th the lead began to close, and hastily packing the sledges we rushed them across over moving fragments of ice. We now found ourselves in a zone of high parallel ridges of rubble ice covered with deep snow. These ridges were caused by successive opening and closing of the lead. When after some time we found a practicable pass through this barrier, we emerged upon a

FIG. 1.—BRINGING OUT THE GREELY RECORDS.

FIG. 2.—FORT CONGER.

OVERLAND ACROSS ELLESMERE LAND.

series of very small but extremely heavy and rugged old floes, the snow on them still deeper and softer than on the southern side of the lead. At the end of a sixteen-hour day I called a halt, though we were only 2 or 3 miles north of the big lead.

During the first portion of the next march we passed over fragments of very heavy old floes, slowly moving eastward. Frequently we were obliged to wait for the pieces to crush close enough together to let us pass from one to the other. Farther on I was compelled to bear away due east by an impracticable area, extending west, northwest, north, and northeast as far as could be seen, and just as we had rounded this and were bearing away to the north again we were brought up by a lead some 50 feet wide. From this on one day was much like another, sometimes doing a little better, sometimes a little worse, but the daily advance, in spite of our best efforts, steadily decreasing. Fog and stormy weather also helped to delay us.

I quote from my journal for April 21:

> The game is off. My dream of sixteen years is ended. It cleared during the night and we got under way this morning. Deep snow. Two small old floes. Then came another region of old rubble and deep snow. A survey from the top of a pinnacle showed this extending north, east, and west, as far as could be seen. The two old floes over which we had just come are the only ones in sight. It is impracticable, and I gave the order to camp. I have made the best fight I knew. I believe it has been a good one. But I can not accomplish the impossible

A few hours after we halted, the ice to the north commenced like the sound of heavy surf, and continued during our stay at this camp. Evidently the floes in that direction were crushing together under the influence of the wind, or, what was perhaps more probable, from the long continuation of the noise, the entire pack was in slow motion to the east. A clear day enabled me to get observations which showed my latitude to be 84° 17′ 27″ north, magnetic variation 99° west. I took some photos of the camp, climbed and floundered through the broken fragments and waist-deep snow for a few hundred yards north of the camp, gave the dogs a double ration, then turned in to sleep, if possible, for a few hours preparatory to returning.

We started on our return soon after midnight of the 21st. It was very thick, wind from the west, and snowing heavily. I hurried our departure in order to utilize as much of our tracks as possible before they were obliterated. It was very difficult to keep the trail in the uncertain light and driving snow. We lost it repeatedly, when we would be obliged to quarter the surface like bird dogs. On reaching the last lead of the upward march, instead of the open water which had interrupted our progress then, our tracks now disappeared under a huge pressure ridge, which I estimated to be from 75 to 100 feet high. Our trail was faulted here by the movement of the floes, and we lost considerable time in picking it up on the other side. This was to me a trying

march. I had had no sleep the night before, and to the physical strain of handling my sledge was added the mental tax of trying to keep the trail. When we finally camped it was only for a few hours, for I recognized that the entire pack was moving slowly, and that our trail was everywhere being faulted and interrupted by new pressure ridges and leads in a way to make our return march nearly if not quite as slow and laborious as the outward one. The following marches were much the same. In crossing one lead I narrowly escaped losing two sledges and the dogs attached to them. Arrived at the "grand canal," as I called the big lead at which I had sent two Eskimos back, the changes had been such as to make the place almost unrecognizable.

Two marches south of the grand canal the changes in the ice had been such, between the time of our upward trip and the return of my two men from the canal, that they, experienced men that they were in all that pertains to ice craft, had been hopelessly bewildered and wandered apparently for at least a day without finding the trail. After their passage other changes had taken place, and as a result I set a compass course for the land and began making a new road. In the next march we picked up our old trail again.

Early in the morning of the 22d we reached the second igloo out from Cape Hecla and camped in a driving snowstorm. At this igloo we were storm bound during the 27th and 28th, getting away on the 29th in the densest fog, and bent on butting our way in a "bee-line" compass course for the land. Floundering through the deep snow and ice, saved from unpleasant falls only by the forewarning of the dogs, we reached Crozier Island after a long and weary march. The band of young ice along the shore had disappeared, crushed up into confused ridges and mounds of irregular blocks.

The floe at the island camp had split in two, the crack passing through our igloo, the halves of which stared at each other across the chasm. This march finished two of my dogs, and three or four more were apparently on their last legs. We did not know how tired we were until we reached the island. The warm foggy weather and the last march together dropped our physical barometer several degrees.

As we now had light sledges, I risked the short cut across the base of Fieldin Peninsula, and camped that night under the lee of View Point. Four more marches carried us to Conger, where we remained three days drying clothing and repairing sledges, and giving the dogs a much-needed rest. Leaving Conger on the 6th of May, 11 marches brought us back to Payer Harbor on the 17th of May. A few days after this I went north to complete the survey of the inner portions of Dobbin Bay, being absent from headquarters some ten days. Open water vetoing a trip which I had planned for June up Buchanan Bay and across to the west coast of Ellesmere Land, the remainder of the

time was devoted to assiduous hunting, in order to secure a supply of meat for the winter in the contingency of no ship arriving.

On the 5th of August the new *Windward* sent north by the club, and bringing to me Mrs. Peary and my little girl, steamed into the harbor. As soon as people and supplies could be hurried aboard her, she steamed across the sound to the Greenland side. Here my faithful Eskimos were landed, and after devoting a week or so to the work of securing sufficient walrus to carry them in comfort through the winter, the *Windward* steamed southward, and after an uneventful voyage arrived at Sydney, C. B., on the 17th of September, where I had the pleasure of meeting Secretary Bridgman of the club, and forwarding through him a brief report of my movements during the past year.

THE FIRST YEAR'S WORK OF THE NATIONAL ANTARCTIC EXPEDITION.[a]

By Sir Clements R. Markham, K. C. B., F. R. S.

We must all, I think, feel that this is a great occasion. We have received news of the splendid work done by our countrymen in the far south, and we are assembled to acquire some idea of the nature of that work, and of the general results. We shall effect this object by means of Mr. Skelton's photographs, and of the best map we have been able to construct with the materials that have reached us. We do not intend to discuss or to describe the scientific results of this work. We have not the means. All that is reserved for the grand day when we welcome the return of Captain Scott and his fellow-explorers to this country. To-night should rather be devoted to an endeavor to understand and to appreciate the high qualities, the indomitable energy, the strict sense of duty, the courage and hardihood which enabled our countrymen to make the extensive discoveries which are shown on the map. They represent an achievement which is quite unsurpassed in my time.

Before following the memorable voyage, I must say a very few words on the subject of the arrangements for the expedition in this country. When the two societies approached the Government with a view to obtaining assistance in June, 1899, Mr. Balfour spoke in the strongest terms of the importance of such an expedition, both from a scientific and a national point of view, and he was told that it would be necessary to build a ship specially adapted for the service, among other reasons for the sake of the magnetic observations. An estimate was submitted to him amounting to £100,000 if the expedition lasted for three years, or £90,000 if for two years. It was decided that the expedition should be for two years. Mr. Balfour promised a parliamentary grant which amounted to £45,000. The public subscribed the other moiety, this society giving £8,000. The *Discovery* was launched, and has proved most admirably adapted for the work. It has been said that she is the most expensive vessel that was ever built in this country for scientific purposes. It is equally true that she is the cheapest. For she is the only vessel that was ever built in this

[a] Read at the Royal Geographical Society, June 10, 1903. Reprinted from The Geographical Journal, London, July, 1903, Vol. XXII, No. 1, pp. 13–20.

country for scientific purposes. She has been a great success, and she will be a great success even if she has to be abandoned in the antarctic ice. The famous voyage performed in her, the vast and important scientific results achieved through her means, will remain forever as the record of her success, even though the staunch old *Discovery* leaves her ribs in the far south. But this will not be if human help, guided by no ordinary ability and skill, can avail. For if the ship is strong and adapted to her work, still stronger and still better are her crew. No more striking proof of this is needed than the way they have rallied round their beloved commander. Captain Scott's deeds speak for themselves, and he was supported by such officers as Armitage, Royds, Skelton, Shackleton, and Barne; by Koettlitz, Wilson, Bernacchi, Hodgson, and Ferrar; and by 26 seamen and marines, all good men and true. Alas that one of the best of all, the devoted and chivalrous Shackleton, is no longer with them! The Admiralty has lent the men, without whom the work could not have been done; but we must always remember that we owe this to the good offices of our lamented associate, Admiral Sir Anthony Hoskins. We owe much more to his memory than even that.

One word with regard to the management of the business of the expedition. Since December, 1900, a joint finance committee, appointed by the councils of the two societies, of which I have been chairman, has transacted all the business. The three other members are the treasurers of the two societies and a distinguished official of the treasury appointed with the approval of Mr. Balfour; these three business men have conducted the affairs of the expedition on business principles. Efficiency has been secured without waste or extravagance, and most especial care was taken with regard to the examination of the provisions by an expert under official supervision. The committee has worked and is still working harmoniously, and there has scarcely been a difference of opinion among its members. As a test of its business capacity, we have the fact that the expedition is well within the estimate, and that the committee had a balance of £7,000 to meet all further expenditure, if the two ships had returned this year in accordance with the instructions. Captain Scott sat on the committee from its commencement until the departure of the *Discovery*.

Under such auspices the expedition left New Zealand on Christmas eve, 1901, and entered the antarctic ice. Her objects were to study the nature of Ross's great ice barrier; if possible, to discover land to the eastward; to secure various scientific results during the voyage and in winter quarters; and from winter quarters to explore the volcanic region, and to make discoveries to the south and inland to the west. Most thoroughly and completely have the explorers carried out these instructions. Their deeds have far exceeded all that I had hoped or even conceived possible. Let us now follow their proceed-

ings, and endeavor to get some notion of their surroundings with the help of Mr. Skelton's photographs.

On reaching safe winter quarters, the great work of sledge traveling was commenced with some autumn journeys. The severity of the weather was intense, both from low temperature—42° to even 57° below zero—and from the furious gales; but the journeys were of great use, both for obtaining information respecting the lay of the land and for the acquisition of experience. There was one fatal accident, which is admirably described by Captain Scott:

Mr. Barne reached the crest of the hills at about noon on March 11, and camped for lunch, during which meal the wind sprang up very suddenly, bringing a heavy drift; the temperature fell, and the party, not experienced in such conditions, suffered much from frostbites and general discomfort. In these circumstances, and imagining themselves closer to the ship than they actually were, they decided to leave the sledges and make for her. Soon after their start the gale increased, and they were enveloped in a whirl of drifting snow and entirely lost their bearings. Mr. Barne did his best to keep the party together, the more so when when it became evident that the slope on which they stood was affording a less and less secure foothold. Before long, however, one of the men, Evans, slipped and disappeared from sight. After shouting and receiving no reply, Mr. Barne, cautioning the men to remain where they were, decided to follow, and very deliberately started to slide down the slope himself. He was firmly under the impression that the slope was one well known to us all close to the ship, and that after making certain he would be easily able to regain the summit and bring the men on. After waiting for some time another of the men (Quartly) decided to follow Mr. Barne and was immediately lost to sight. The experience of these three was identical; after the first start they were soon going at a speed which left them absolutely no control of their movements, and this continued for some 400 or 500 yards, until they were suddenly brought up in a patch of soft snow within 15 feet of a sheer drop into the sea.

Meanwhile, of the party above, one, Hare, had decided to go back to the sledge to change his footgear, and the remaining five, after a long wait, proceeded along the slope, as they supposed, toward the ship, led by an able seaman (Wild). Luckily, Wild had nails in his boots, for, after traveling some distance, he suddenly and without warning (so thick was the snow) found himself within an ace of stepping over the cliff into the sea. He had the presence of mind to shout to the others to stop, which they were all able to do except poor Vince, who missed his footing, shot past Wild, and was immediately lost to view. Vince was a thoroughly good man, always cheerful and bright, and popular throughout the ship. With great difficulty the remaining four men succeeded in retracing their steps, and eventually reached the crest of the hill, from whence, taking a more easterly course, they fell on some landmarks and found their way to the ship. Great credit is due to Wild for the manner in which he conducted and kept together the small party.

A large search party was immediately dispatched on their return to the ship, and the siren was kept going. With some difficulty the search party succeeded in finding the sledges, and in the vicinity they found Mr. Barne, Evans, and Quartly half frozen and wholly dazed; they did not know how they had again reached the summit of the hill. No trace was found of Hare or Vince. A further prolonged search was made on the following day, a roped party descending the slope with crampons, but without result. On the third day I got up steam on the bare possibility of finding an ice-foot below the ice cliff over which Vince had fallen, and while we were preparing to weigh Hare was seen descending the hill opposite the ship. He was

quickly brought on board, and found to be neither frost-bitten nor in any way hurt by his exposure; he had turned to find the sledges, failed to do so, wandered aimlessly about, and finally lost consciousness; thirty-six hours later he awoke, to find himself buried in snow and only a trifle stiff. He imagined it to be the morning after the accident, and was astounded to learn that he had slept through a whole day.

On taking the ship around to the scene of the accident we found an ice-foot, and it was evident that Vince must have fallen directly into the sea from a cliff 150 to 200 feet in height.

When Captain Scott addressed the ship's company in a few words after service on the following Sunday, there was scarcely a dry eye. All mourned the loss of their comrade, George Vince, a cheerful and popular messmate and an excellent seaman.

The winter passed cheerfully. There were plenty of amusements, but there was also plenty of hard work. Mr. Bernacchi tended his magnetic instruments with zealous care, and took regular observations with the electrometer. The temperature and salinity of sea water at various depths were ascertained. Mr. Hodgson was indefatigable in all weathers, keeping holes open in the ice for his nets and fish traps. Doctor Wilson's work, as regards vertebrates, is exceedingly valuable, and I am assured that the biological collections are most important and will form one of the great features of the expedition. The meteorology is under the charge of Lieutenant Boyds, and nothing can exceed his care and diligence. A series of meteorological observations for two years in 77° 50′ S., more than 500 miles farther south than any ship has ever wintered before, will be most valuable.

As the sun began to return, the magnificent range of mountains to the westward began to appear in surpassing grandeur. The glow of the sun when it was still below the horizon just caught them, and the sides facing the north were lit up with a pinkish-orange tint, the other sides being dark and shadowy. In September the early spring traveling commenced, when the cold was even more intense than in the autumn. Royds and Skelton were the chief explorers of the volcanic island on which Erebus and Terror rear their giant cones. With four men they were away twenty-one days, with the thermometer always −40°, and once as low as −58°. This cold is too intense for sledging, and in addition they encountered a furious gale, which lasted for five days. In spite of the weather, Skelton and two men found a way over the big ice ridges of the barrier down to the sea edge, using crampons and ice axes, and being roped together. A close examination was thus made of the position where the barrier abuts upon the land at Cape Crozier. In a subsequent journey Royds found the post cairn at this point and deposited a notice for the relief ship.

There were several sledging journeys for short distances conducted by the scientific staff, chiefly with the object of geological investigations, but the great results were to be obtained from the southern and western parties.

Captain Scott established a depot 60 miles to the south in a journey of ten days, from September 23 to October 4, when there was a heavy gale, and the thermometer fell to −51°. On November 1 he started with 18 dogs, accompanied by Lieutenant Shackleton and Doctor Wilson. A supporting sledge under Lieutenant Barne went as far as the first depot. At first all went well, but after a fortnight the dogs got weaker and weaker, and a long tract of soft snow had to be crossed, which occupied them for thirty days, bringing the sledges up in relays. Practically the dogs became useless. The explorers had to do all the work themselves. But, nothing daunted, the gallant men pushed onward, lightening the weight by leaving a depot in 80° 30′ S.

They reached 82° 17′ S. On their return Lieutenant Shackleton broke a blood vessel, and was only just able, owing to his extraordinary pluck, to keep up with the sledge; while Scott and Wilson, suffering from snow-blindness and hunger, dragged the sledge back, 240 pounds each, and reached the ship on February 4, after an absence of ninety-four days.

I calculate that they must have gone over 981 statute miles. The story will be told by Scott himself—a story of heroic perseverance to obtain great results; a story which is unmatched in polar annals. It will tell us, too, of new geographical facts and deductions of intense interest; of a new and hitherto unknown world in the far south, reached with such extreme difficulty—

> Yet even here Britannia's flag has thrown
> Her shadow on the ice, and hailed the land her own.

The achievement of the great western party, dragging sledges over mountains and glaciers, with such leaders as Armitage and Shackleton, is only second to Scott's memorable journey. They were dragging 240 pounds per man; first over 29 miles of sea ice, and then for 19 miles up a snow-filled valley to the foot of the mountains. They also had to work by relays. Crampons, blocks and tackles, ice axes, and crowbars were needed; and so they climbed the ice slopes with loaded sledges, and traveled many miles over bare blue glacier amidst magnificent scenery, reaching an elevation of 9,000 feet, at a distance of 142 statute miles inland from the ship as the crow flies. They were fifty-three days away.

The loss of the dogs was felt as a great calamity, because each dog was given in charge to a man, who became much attached to it. There are, however, several puppies.

Another calamity was the loss of all the boats, which during the winter got frozen into a mass of solid ice. After hacking at this ice for months, it was found impossible to extricate the boats.

But now all the traveling parties had returned, and the longed-for relief ship *Morning* hove in sight on the 23d of last January.

The meeting is acquainted with the history of the relief ship; how she was bought, fitted out, equipped, and dispatched last year by the Geographical Society, with funds subscribed almost entirely by our fellows. We all know the great dangers of polar navigation, and that a ship in those regions may be in need of succor after the first winter. Consequently, annual communication has been the rule with all government expeditions since the Franklin disaster. We were bound to follow this example, and the necessity for our action has since been proved.

The *Morning*, fitted up with provisions, including a good supply of frozen meat, and coals for the *Discovery*, left Lyttelton, New Zealand, on December 6, and crossed the Antarctic Circle on Christmas Day. She is commanded by Captain Colbeck, a very able and capable ice navigator, who has under him zealous officers and a good crew. In about 67° 40′ S. an interesting discovery was made of a new island, of which several excellent photographs were taken. A landing was effected and a survey was made; it was named Scott Island.

Outside the pack the *Morning* encountered a heavy southeast gale, bergs and heavy floe pieces being a source of continual danger, and the ship was subjected to a most severe straining. At one time she could show no canvas. The season was very late and the navigation difficult. But Captain Colbeck followed up his clew, found the record at Cape Crozier, and finally sighted the *Discovery's* masts.

It was found that several miles of ice intervened between the two ships, and it was not long before it became clear that the ice was not likely to move during that season. All hands at once went to work to transfer stores and provisions on sledges, and before it became necessary to depart the *Morning* had supplied 14 tons of stores and provisions and 20 tons of coal. But there was barely time.

The arrival of the *Morning* was most providential, but she leaves the *Discovery* with only provisions to last until next January, and 80 tons of coal.

In returning, the *Morning* was in some danger of being detained. She was beset, but was saved by her skillful ice navigation, aided by a strong southwesterly gale. Her detention would have been a terrible calamity. She, however, returned safely to Lyttelton, New Zealand, last March.

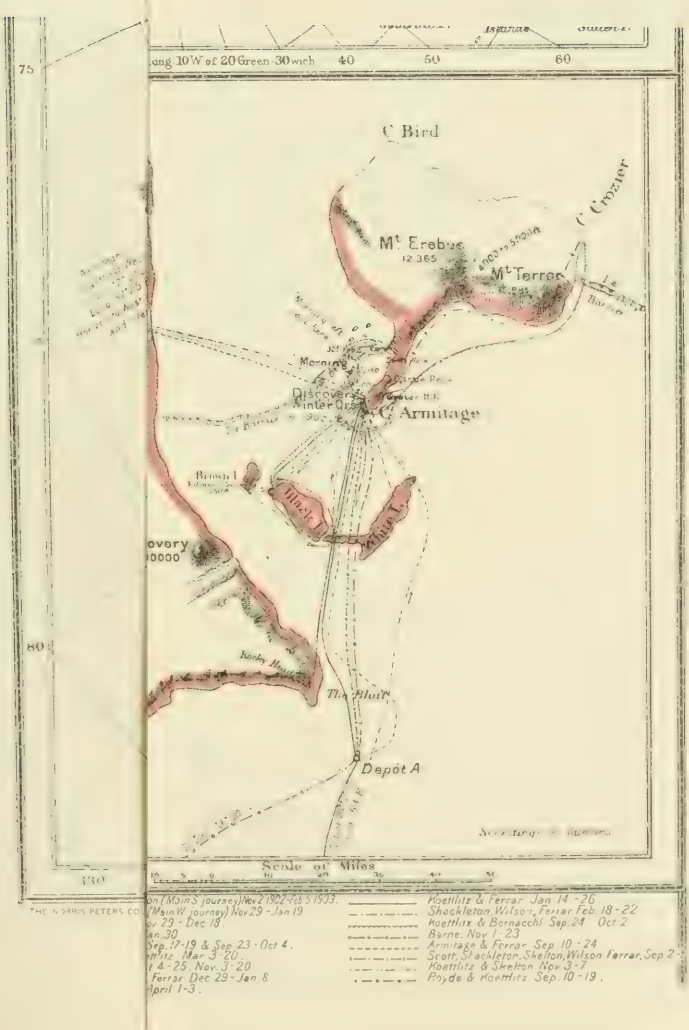
Captain Colbeck deserves high commendation for the skill and ability with which he conducted a very arduous and difficult voyage; for his excellent judgment in finding the winter quarters of the *Discovery*, his rapid transfer of stores, and the seamanlike qualities which enabled him to work his vessel safely out of the ice under circumstances of no ordinary difficulty. The officers worked under him with zeal and intelligence, and the conduct of the men was excellent throughout the voyage.

It will be seen that a second voyage of the *Morning* is absolutely necessary for the safety of our gallant countrymen. There are 37 souls in the Antarctic ice, consisting of 5 naval officers, 1 officer of the naval reserve, 5 members of the scientific staff, 24 naval seamen and marines, and 2 other good men. We have a balance of £7,000. Only a small additional sum is needed, namely, £12,000. Without it those heroes who have done so much for science and their country's credit will be in grave peril.

We must provide for wages for both ships; we must send out the means of blasting and forcing the *Discovery* out of her icy prison; we must repair the *Morning*, so terribly strained and knocked about; we must store her with coal and provisions.

There are difficulties and dangers yet, but the chief dangers are financial. Our gallant Colbeck and his people will overcome the rest. Meanwhile, the heroic Discoverers are still working for us at their numerous observations under increasing hardships caused by the small stock of coal. They have full faith in us, and that the needful funds will be found by us. Look once more at your maps. Look at their discoveries. Do not these men deserve well of their country? Will not their country recognize their services? I feel sure that it will, and that we shall yet welcome them all here after one of the most successful and glorious achievements that have ever adorned our geographical annals.

Note on the Antarctic Sketch-map.—As the complete charts showing the results of the surveys made by Captain Scott and the officers serving under him have not yet been received, the map of the Antarctic regions which accompanies this paper must be considered as only provisional. It has been prepared from all the information at present available, including the report which Captain Scott has addressed to the presidents of the Royal Society and the Royal Geographical Society. A rough sketch of the winter quarters of the *Discovery* by Lieutenant Barne, and another of Erebus and Terror Island by Lieutenant Royds, have furnished the basis for the enlarged inset plan, but the remainder of the new work has been drawn from letters and reports, in which are, however, given the latitudes and longitudes of several positions. The track of the *Morning* has been approximately laid down, from a preliminary chart on a small scale, by Lieutenant Evans and sent home by Captain Colbeck. Lieutenant Shackleton has, since his return, looked over a proof of the map and made several corrections, but until the complete charts, based upon numerous observations and careful surveys, arrive, it is, of course, impossible to give anything more than an approximate idea of the geographical work of the expedition. Upon the present map the newly discovered land is shown in red, while the remainder of the coast line has been principally taken from the Admiralty charts and other material.



C Bird
C Crozier
Mt Erebus
12 365
Mt Terror
Morning
Discovery
Winter Qrs
C Armitage
Brown I.
Black I.
White I.
Rocky Head
The Bluff
Depot A
Long. 10 W of 20 Green-30 wich
40
50
60
75
80
180
Scale of Miles
Koettlitz & Ferrar Jan 14 - 26.
Shackleton, Wilson, Ferrar Feb. 18 - 22
Koettlitz & Bernacchi Sep. 24 Oct 2
Barne. Nov 1 - 23
Armitage & Ferrar Sep 10 - 24
Scott, Shackleton, Skelton, Wilson Ferrar, Sep 2
Koettlitz & Skelton Nov 3 - 7
Royds & Koettlitz Sep. 10 - 19.
(Main S journey) Nov 2 1902 - Feb 5 1903.
(Main W journey) Nov 29 - Jan 19
Sep. 17 - 19 & Sep 23 - Oct 4.
Mar 3 - 20.
Nov. 3 - 20
Ferrar Dec 29 - Jan. 8
April 1 - 3.
THE NORRIS PETERS CO


AUSTRALIA
TASMANIA
NEW ZEALAND
Auckland I.
Campbell I.
Macquarie I.
SOUTH
VICTORIA
LAND
Sabrina
Clarie
Adelie
Knox
Kemp L.
Enderby L.
Alexander
Graham Land
King Edward VII Land
C. North
Robertson Bay
Adare
Admiralty Range
SOUTH VICTORIA LAND
Sabine Mt. 10,000
Lady Newnes Bay
Coulman I.
Wood Bay
Mt. Melbourne
Mt. Discovery
BARRIER
The height varies from 30 to 280 ft.
KING EDWARD VII LAND
Mt. Discovery
C. Bird
Mt. Erebus
Mt. Terror
C. Crozier
C. Armitage
SKETCH MAP
Showing
The first year's work of
THE NATIONAL ANTARCTIC EXPEDITION
to illustrate the paper by
SIR CLEMENTS MARKHAM, K.C.B.
Scale of Miles
Track of "Discovery"
Track of "Morning" (outward)
Sledge journeys
(return)
Newly discovered land

THE SWEDISH ANTARCTIC EXPEDITION [a]

By Otto Nordenskiöld and Others.

I. Summary of Events.

By the Editor of The Geographical Journal.

We print below a summary of the scientific results of the Swedish Antarctic Expedition of 1902-3, kindly communicated to us by Doctor Nordenskiöld. It is necessary, however, to preface this by an outline of the course of the expedition from the time when the *Antarctic* steamed north, on February 21, 1902, after leaving the leader and his five companions in the inhospitable neighborhood of Snow Hill, on the eastern side of the northward-pointing land mass known as Louis Philippe Land. The first business which engaged the attention of the explorers was the erection of houses and observatories, after which an attempt was made to explore the neighborhood by means of a boat excursion. It was soon found that the season was too far advanced for work of the kind, the movements of the pack placing the boat in frequent danger. Enough was done to show that Seymour Island, as well as that on which the winter station had been established, was divided from the mainland by a channel representing the supposed Admiralty Inlet; but further exploration had to be postponed until the sea should once more be frozen over. The terrific gales experienced during the winter and the work done during that trying period are spoken of in Doctor Nordenskiöld's paper, and we may therefore pass on to the first important sledge expedition, which was begun on September 30, the leader being accompanied by Lieutenant Sobral and the sailor Jonasen. Of the two sledges taken, one only could be pulled by the dogs, the numbers of which had sadly diminished by this time. Progress was therefore somewhat slow. It soon proved that the outer fringe of islands was backed by a continuous mainland, connecting Louis Philippe Land with King Oscar Land farther south. The space between the islands was occupied by ice plains, terminating in a precipitous ice wall, and apparently resembling the surface of

[a] Reprinted from The Geographical Journal, London, Vol. XXIII, No. 2, February, 1904.

Ross's famous barrier in the vicinity of Victoria Land. The surface was generally smooth, but, as was found by the British explorers in the opposite hemisphere, the approach to the land was barred by formidable crevasses, rendering it impossible to obtain seal meat for the dogs, so that it became necessary to begin the return journey on October 21, or earlier than had been anticipated, the station being again reached on November 4.

During the summer the gales ceased almost entirely, and little change in the ice occurred, this being the reason for the failure of the *Antarctic* to reach the station to take home the explorers. The second winter which they were thus forced to spend at the station proved far better than the former as regards the gales experienced, but the renewal of sledge expeditions, apart from some minor trips, was again reserved for the spring. On September 29, Doctor Nordenskiöld started, with the sailor Jonasen as his only companion, intending to examine the channels northward in the direction of Erebus Gulf. This was reached on October 12, when the explorers unexpectedly met with Doctor Andersson and Lieutenant Duse, who had spent the winter in that locality without any suitable equipment, having left the *Antarctic* at the end of 1902, in order to try to reach the winter station overland. They had since heard nothing of the ship. Returning in company to the winter station, they arrived in time to greet the appearance of the Argentine gunboat *Uruguay* (Captain Irizar), which arrived on November 8, still without news of the *Antarctic*. The very same night their fears for the safety of the crew were set at rest by the arrival of Captain Larson and four men, who had made their way from the spot where the crew had wintered after the loss of the ship, the fate of which was thus for the first time made known to the other parties. The catastrophe had occurred when the *Antarctic* was about 20 miles south from Dundee Island, the ship having been crushed by the ice pressure caused by a violent gale on January 10, and finally abandoned on February 12, the crew making their way amid great difficulties to Paulet Island. The various parties being happily reunited on the arrival of the *Uruguay* at the last-named island on November 11, the homeward voyage was commenced.

II. Scientific Work at the Winter Station.

By Dr. Otto Nordenskiöld.

We arrived at the place selected for our winter station, at the foot of Snow Hill, in Admiralty Inlet, on February 12, 1902, and on February 21 our ship, the *Antarctic*, finally left us, not for some months, as we expected, but never to return. The members of the winter party, besides myself, were Doctor Bodman, meteorologist and magnetician; Doctor Ekelöf, physician and bacteriologist; Lieutenant Sobral,

of the Argentine navy, assistant meteorologist, and two sailors. As soon as possible the observations were started, and the scientific work was carried on without interruption until November 8, 1903, the day of the arrival of the Argentine relief expedition, commanded by Captain Irizar.

In the preliminary plan of the expedition the meteorological observations are entered as one of the most important parts of our work. But it is not only their intrinsic interest that makes me, in trying to give a general view of the physical geography of the region, begin with a discussion of our meteorological observations. In fact, not only is the climate of that region of specially great geographical importance, but there are some rather unexpected features that seem to lend that section of our results a peculiar interest.

The principal meteorological features of the region appear in the following table, communicated by Doctor Bodman, and comprising the approximate monthly means of temperature, barometic pressure, and velocity of the wind:

	Temperature.	Barometer.	Velocity of wind.
1902.	° F.	*Inches.*	*Ft. per sec.*
March	14.90	29.25	30.84
April	7.88	29.31	23.95
May	1.40	29.12	36.74
June	- .58	29.34	36.74
July	- 11.92	29.29	36.09
August	- 8.50	28.96	28.54
September	6.26	29.10	26.25
October	9.14	28.99	30.51
November	17.42	29.28	24.61
December	28.40	29.26	13.12
1903.			
January	30.38	29.28	19.69
February	25.70	29.05	22.97
March	11.48	28.96	44.29
April	6.44	29.07	26.25
May	— 2.92	29.18	19.69
June	— 6.34	29.13	19.69
July	.86	28.95	26.25
August	2.48	29.12	27.89
September	1.22	29.18	....
October	20.48	29.02	....
March, 1902–February, 1903	10.04	29.19	27.56

The minimum for the whole time was in August, 1902, —42.16°; the maximum in the same month of August, 1903, 48.74°.

As other meteorological questions will soon be discussed more extensively by Doctor Bodman, I here restrict myself to those most important for the climate, viz, the temperature and the velocity of the wind. The first thing shown by this table is the unexpectedly low mean temperature. According to approximate calculations of our astronomical observations, the situation of the winter station was in 64° 22′ south and 57° west. The nearest places where meteorological observations have been carried out during a time of sufficient length are at Cape Horn and in the region where the *Belgica* wintered, and from the results thus obtained we might have expected to find

here a yearly mean of about 20° or 25° Fahrenheit. Instead of this we obtained for the first year +10.04° Fahrenheit. Though it is possible that this temperature is somewhat lower than general, as the summer was undoubtedly exceptionally cold, and even the mean for the eight colder months (March–October) was in the first year 2.3° Fahrenheit, but in the second 4°, it does not seem probable that the difference from that general mean temperature should be even so great as between the two winters. A mean temperature of 10° Fahrenheit at the same distance from the pole is in the northern hemisphere found in the environs of Hudson Strait, and in Siberia, in the region of Yakutsk, still one or two degrees farther south. In both cases we see the influence of the extremely low winter temperatures of a continental climate, while for a thoroughly marine climate the temperature is unexpectedly low. It must be left to the discussion of the observations of the other expeditions contemporaneous with ours, including the *Scotia* expedition, to discover whether there exists an especially cold area on the east coast of Graham Land, or even south of the Atlantic Ocean.

The difference in temperature between summer and winter is, of course, not so great as in the regions mentioned, and, notwithstanding that the temperature of the three winter months was during the two years as low as −4° Fahrenheit, the winter could not be called very cold if it was not for the wind. The great violence of the wind in all antarctic regions is a well-known fact, but I doubt if a violence such as that during our first winter has ever been experienced in an arctic or antarctic climate, and even the average for the whole time must be considered unexpectedly high.[a] However, the table shows that the differences between different seasons, and also between different years, are very great.

The factor that really determines the climate is the direction of the wind. The situation of the station, on the shore of a strait, may partially account for the predominance of the winds from the southwest and northeast quadrants. Besides this, there is a high percentage of calm, or nearly calm, weather. The southwest winds are by far the most common and the strongest, and because they are also the coldest all the really bad weather is to be ascribed to them. The calm hours are not much warmer, but of course their influence on the general feeling is absolutely different. The real northeast winds are comparatively strong and cold; but, besides them, there is another class of winds which are, if not as common as the others, still exceedingly characteristic of the climate. They are the winds from north or even north-northwest, and when once started they are very strong and very

[a] The only similar observations from the Antarctic hitherto published are those by the Borchgrevink expedition (preliminary), the mean being considerably lower than ours.

long continued, and bring the warmest weather. It is these differences that bring out another characteristic of the climate—its great variability. The variations from day to day are in winter time greater, as in most other regions of the world, and, as far as our short experience goes, it is quite probable that this also holds good from year to year. Though the mean temperature of these two winters is nearly the same, the difference between the two is very great. In the first year the southwest storms were absolutely overwhelming, alternating with periods of calm, warmer weather. In the second year the calm periods were generally colder, and, at least during the first part of the winter, very common and long continued, and to this cause during the second half were due long periods of warm northerly winds.

In the closest connection with that state of the weather stand the ice conditions. After the winter of 1902, with its southwest storms, came a summer that was not only the coldest hitherto known in any region of the world, but also, and that to our bad luck, marked by an accumulation of ice such as never has been seen in that region. It was in the battle with that ice that the *Antarctic* was lost, but it may be said that we on the station had really no reason for uneasiness, as never, except perhaps for two or three days, was the sea in our neighborhood so free from ice as to render the arrival of the ship probable. On the other hand, even in the middle of the winter, the north and northwest winds would cause large openings in the ice, and after the strong gales in August to October, 1903, the second summer started with an almost clear sea, and probably this year is of the same type as the summer of 1893–4, when Larsen made his well-known voyage south.

During our stay I brought together rich material from investigations on the ice, both sea ice and land ice, and especially that typical Antarctic ice cap of Snow Hill—its temperature compared with that of the sea ice and the soil, its movement, surface structure, and stratification. Interesting is the great accumulation of snow during the summer 1902-3, which is important for explaining the formation of such ice caps and their great extension in those regions; a few years such as this would cover the whole region with snow.

Because of this accumulation the land ice forms at all seasons an easy traveling road, and only where there are large crevasses it might be difficult to pass in summer time. On the contrary, just as in the north, so also here the sea ice is during the summer to a great extent covered by water, making the traveling very difficult. But even if this had not been the case we could not have used the first summer for distant sledge traveling, as we had then to wait for the return of the *Antarctic*, and later to provide ourselves with the supplies necessary for another wintering. All sledge work, therefore, was mainly during the two springs. Its results have been the survey of the coast with its outlying islands from the end of Louis Philippe Land to our southernmost

point in 66° south, 62° west. The accompanying rough sketch-map, compiled by Lieutenant Duse, gives an idea of the general geography of the region rather different from older maps. As a matter of fact, the whole mainland from Louis Philippe Land past King Oscar Land forms a narrow strip of high mountainous land, the continuation of Graham Land. Farther on in the same direction, Joinville Island seems really an archipelago of islands. East of the mainland we find two other island groups, divided by the wide gulf extending between Snow Hill and Robertson Island.

The northern archipelago is divided from the mainland by a broad channel studded with islands. It consists of two groups, divided by Admiralty Sound, with its two islands, Cockburn and Lockyer. Inside of this strait the principal mass of land is divided by a narrow winding channel into two large islands, the largest of which, with Mount Haddington for its highest point, I propose to call, after its discoverer, James Ross Island. Though in cold summers the ice in those channels and straits does not break up, it is probable that there is in other years much open water.

Very different is the aspect of the southern "archipelago." No real islands exist here; even the mildest summer will not melt away the ice so as to allow a boat to come round any of the islands. All visible land consists of nunataks rising out of a high, extensive mass of ice. Still, I believe it is very probable that should once there come a change to a warmer climate, then the ice would be found to rest for a great part in a shallow sea, and not only on the land, forming in reality a connection between the mainland and a group of outlying islands. The mainland, so far as known, is composed of crystalline rocks, mostly granites, and also porphyries, and, as shown by Doctor Andersson, though perhaps to a less extent, of folded sedimentary rocks of pre-Cretaceous age. On the contrary, in all parts of the eastern archipelago, young volcanic rocks are in predominance, while granitoid rocks are entirely wanting. What is found is mostly basalt, and to a great extent tufaceous rocks, sometimes belonging to types of great petrographical interest. I need not state that, as a consequence of this geological difference, the mountain forms and the whole aspect of the country show very marked contrasts.

Among the southern nunataks I have only observed volcanic rocks. Besides those, there occurs in the northern region, around our station, another far more interesting series of rocks. Those are the fossiliferous sedimentary rocks, generally sandstones, that are to be found cropping out at the foot of the hills below the volcanic series in most parts of Ross Island, and also on Cockburn Island, and which form the whole of the two large outlying islands, Snow Hill and Seymour islands. The study of those rocks and their fossils will be of great interest for the knowledge of the conditions of those regions in former

times, though it is, of course, impossible at this time to go further into the matter. The whole formation is generally very rich in rather well-preserved fossils, belonging to numerous groups of marine forms. In the lower part ammonites are common, and the age must be considered as Mesozoic; higher up those are wanting, and it is not improbable that the strata here pass into the Tertiary.

It is in those upper strata that I found numerous plant remains, and also remains of some vertebrate animals, showing not only that in a period geologically not very distant, land has existed in this region, but also that the climate was at that time mild, and the land covered by vegetation and inhabited by animals. There is in all this, in the whole configuration of the country as well as in its geology, a very marked analogy to Patagonia, and further studies may prove the resemblance to be still greater. Even the inner channels are interesting, because of their analogy with the great plains and the lakes on the eastern side of the Cordillera. But it seems undeniable that there are great differences in the structure of the southern Cordillera and the Antarctic mountain chain, and more investigation is necessary to determine whether it is possible to consider this part of Antarctica as a continuation of the South American continent or not.

Of our other investigations I will here only mention the bacteriological work. Just as in the Arctic regions, bacteria are also here scarce; but Doctor Ekelöf has made the interesting observation that in the upper layers of the soil there is to be found a comparatively rich flora.

Our studies came to rather an abrupt end with the arrival of the Argentina relief expedition, as we thought we had reasons to expect that we should have a good deal of the summer at our disposal. Still, the time has been long, and undoubtedly it has been an advantage that the scientific work could be continued two years instead of one.

III. The Scientific Operations on Board the Antarctic in the Summer 1902–1903.

By Dr. J. Gunnar Andersson.

On November 5, 1902, the *Antarctic* left Ushuaia for the south. The ship had been thoroughly equipped for the coming cruise in the Antarctic sea; a full supply of coal was taken on board, together with some additional provisions in case of having to winter. A plan for a relief expedition was sent to Sweden and to the Scandinavian general consulate in Buenos Ayres.

As I had been told that coal had been recently discovered in Tekenika Bay, in the southern part of the Fuegian Archipelago, I so arranged our route southward that we stopped two days in this bay to survey the coal-bearing formation. This led to an unexpected result. Instead

of what I had expected to meet here, an isolated patch—like that in Slogget Bay—of the Tertiary formation, with plant fossils and lignite, which is widely distributed in northern Tierra del Fuego, and, in my opinion, more recent than the folding period of the Fuegian cordillera, I found a strongly folded sedimentary series, chiefly a conglomerate, with marine shells and trunks of driftwood. The sedimentary beds were traversed by eruptive dikes. Unfortunately my collections from this place were lost with the *Antarctic*. For this reason I can not give any definite opinion as to the age of the sedimentary beds nor the petrological character of the eruptions traversing them. Moreover, I have decided to return to Tekenika Bay to survey in detail this locality, as it will evidently contribute to deciding the unsettled age of the Fuegian cordillera.

Late in the evening of November 7 the *Antarctic* crossed the latitude of Cape Horn to the west of Hermit Island, and in the night of the 9th to 10th of the same month, in latitude 59° 30′ south, longitude 66° west, we passed the first water-worn floes of drift sea ice, the first iceberg having been sighted the previous day. As soon as we had entered the region of drift ice, I started regular observations on the frequency and size of sea ice and icebergs. These running observations were carried on by me up to my departure from the ship on December 29, and after that they were continued by Mr. Skottsberg.

On November 11–12 we met the dense pack in latitude 61° south, and only after ten days' hard work did Captain Larsen force a way to the open coast water outside the South Shetland Islands. Between Smith Island and Snow Island we entered Bransfield Strait, practically free from ice. November 23–24 we visited Deception Island, but found its crater covered by unbroken ice. From here we steered for the eastern end of Livingstone Island, where a short landing was made. During all this time the weather was fine and clear. On the opposite side of the broad strait we distinctly sighted the snow-clad plateaus and lofty peaks round the Orleans channel—the old Trinity Land. But nothing was to be seen of Middle Island, which is marked on the charts as situated in the middle of the strait between McFarlane Sound and Astrolabe Island; on the following day (25th) we crossed the position of the nonexisting island, and here dropped the lead in 800 fathoms. On the previous day, in a sounding between Deception and Livingstone islands, in 534 fathoms depth, we had found a remarkably low-bottom temperature of 29° Fahrenheit. An examination of the intermediate depths at the sounding station of Middle Island, gave the result that Bransfield Strait repeats the typical hydrographical condition of all ice-bearing parts of the ocean—a superficial layer and a deep-water mass, both characterized by low temperature, and between them a body of relatively warm water. But this section shows two remarkable features: the intermediate warm current is

here faintly developed, and in consequence a very large part of the section is occupied by the bottom water, the temperature of which is only 29.66° to 29° Fahrenheit, the latter at the bottom itself. This bottom temperature is somewhat below the minimum deep temperature hitherto observed in the ocean (the Norwegian Sea, bottom temperature 29.3° Fahrenheit), and it is quite exceptional in the south polar regions, the bottom temperature of the Antarctic Ocean being about 31° Fahrenheit. Evidently Bransfield Strait is an isolated basin, separated from the open ocean by submarine shelves, which admit only a very limited renewal of the warm water. Later on in the summer we got more sections and single soundings in Bransfield Strait. The maximum depth observed was 826 fathoms, near to Bridgeman Island.

In January of the same year (1902), before establishing the winter station, Doctor Nordenskiöld, with the *Antarctic*, made a two days' excursion along the coast of Graham Land southwest from Astrolabe Island. As a result of this visit he was convinced that here runs a continuous coast line, and that the Orleans channel of Dumont d'Urville and the Belgica (later Gerlache) Strait of the Belgian expedition form parts of the same far-extending channel. But the question was in some principal points unsettled, because of the difficulty of reaching an incontestable connection with the Belgian chart. Now, we had to clear it up decisively, and in the time—November 26 to December 5—Lieutenant Duse carried out a survey on the scale of 1:300,000 of the region between Astrolabe Island and Cape Murray (Cape Neyt of the Belgian chart). During this time the hard-working cartographer arranged the course of the ship so as best to suit his survey, we other scientists taking the chances thus offered for our own work. At every landing that Mr. Duse made to get bearings and astronomical observations he was followed by the botanist and the geologist; Mr. K. A. Andersson, in the meantime, with trawlings from the ship, making collections of the luxuriant marine fauna. These days in the Orleans channel we remember as a most happy time of full and profitable activity, the only regret being that the larger mass of its rich collections no longer exists.

On December 5, the survey of the Orleans Channel being finished, we headed for the sound between the mainland and Joinville Island in order to proceed to the winter station. Cheerfully we spoke of the approaching meeting with Nordenskiöld and his comrades, and preparations were made for their reception on board, but events turned out far otherwise than we expected and many a lonely day had to pass before we reached our friends on Snow Hill. The sound inside Joinville Island we always found filled with heavy, hummocky drift ice; and Erebus and Terror Gulf, as far as we could sight it from the sound, looked like a dazzling white plain without a single space of open water

visible. Here all efforts to penetrate the pack would evidently be useless, at least for the next few weeks, and Captain Larsen determined to try outside of Joinville Island. On the northern coast of this island we again met the edge of the dense pack, which we followed in a northerly direction, eagerly looking for an opening to the east and south. South from the Elephant Islands the *Antarctic* got caught by the ice and drifted with it in a northeasterly direction. On December 15 (latitude 61° 35′ south, longitude 53° west) we had drifted outside the Bransfield basin, as was proved by a sounding at 892 fathoms, a bottom temperature of 31.28° F., the normal deep temperature of the open Antarctic Ocean. Two days later, the ice having slackened so as to permit the ship moving, Captain Larsen made his way back westward to open water. We now returned to the sound inside Joinville Island, only to find the ice conditions here unaltered. The chances of reaching the winter station with the ship at this time seemed very bad, and we sought to realize a plan that had been under preparation during the last two weeks. On December 29 Mr. Duse, Sailor Grunden, and I were landed on the west side of the sound to try sledging round the gulf to get into communication with Snow Hill. The movements of the *Antarctic* from this day to the final disaster will be reported by another hand.[a] The only thing that remains to tell here is the fate of the scientific materials on board at this time.

The most valuable part of our collections of earlier times by the expedition had been sent home from Port Stanley and Ushuaia. Before we left Port Stanley the last time (September, 1902), I had left another large part of our collections in charge of the Colonial Government and of the Falkland Island Company. All zoological, botanical, and geological material that could, if wanted, be worked out by foreign hands was deposited here. My private geological notebooks, as well as all the materials in charge of Mr. Duse (meteorological and hydrographical journals, cartographical material), were kept on board to be worked out in the course of the voyage. We are highly indebted to Captain Larsen and the two scientists remaining with him on board for saving all the notebooks, journals, etc. Only the cartographical material from South Georgia could not be found by them, and it was consequently lost with the ship. The collections made on the second visit to Tierra del Fuego were kept on board, and the most of these, as well as most of the collections obtained during that last summer's work in the south, had to be left on board when the sinking ship was abandoned. But it is much to the credit of Messrs. K. A. Andersson and Skottsberg that they, in the days when the fate of the ship was already evident, selected the most valuable, portable parts of their collections, which they took to Paulet Island, and thus saved them.

[a] See above.

IV. The Sledge Expedition from the "Antarctic."

By Dr. J. Gunnar Andersson.

When, in the middle of December, we had found that the impenetrable pack in every direction stopped the ship in its passage toward the winter station, I determined to try to reach Snow Hill by a sledge voyage round Erebus and Terror Gulf. Mr. Duse instantly expressed his desire to take part in the proposed trip, and also the third member wanted, Sailor T. Grunden, joined voluntarily.

Without any special equipment for sledge traveling, and starting along an unknown coast, we evidently entered on a rather doubtful and hazardous undertaking, but the situation required everything possible to be tried. As soon as the necessary preparations were made, we landed in a bay on the mainland (west) coast of the sound inside Joinville Island where a depot of provisions was erected. Before the departure the following was agreed with Captain Larson: That (1) if the sledge party reached the station, we should wait there for the *Antarctic* until February 10, but after that date bring Nordenskiöld and his comrades out to our starting point. In this case Larson had to pick us up at the place agreed on between February 25 and March 10. (2) If the *Antarctic* reached the station, and we did not appear there by January 25, Larson had to look for us at our depot.

On the night following our landing, we started in a south-southwest direction across the inland ice, and on the second day we made an unexpected discovery. Having reached an ice shed we faced a broad sound with scattered islands. This sound we had to cross to reach a snow-covered land lying some 22 miles distant in a southerly direction. The sea ice was at this season in a very miserable state, covered with large fresh-water pools. These were getting deeper and formed a regular network as we approached the last-named land, which we reached (January 3, 1903) only after a desperate wading and with all our effects thoroughly wet. After having climbed to the top of the gently sloping inland ice, we got a free view all round that cleared up our position. The land where we were standing formed in reality a large island on the north side of the water called by Sir James Ross, Sidney Herbert Bay, which in fact runs far inland and joins our island inside with the broad water that we had just passed. Sidney Herbert Sound was all over a bluish surface of water-covered ice, quite similar to that on which we had just had a narrow escape, and along the shores there were in some places broad spaces where the ice was entirely gone. As we could not think of crossing this sound, we could only give up our plan and return to the depot, which we reached on January 13. Here the weeks passed without the *Antarctic* reappearing, and in the middle of February we began to make preparations for the chance that we might be forced to winter here. On March 10, the time to expect

the ship was due, and the following day our stone hut was ready for use. The depot had been established only for the time until the ship should return, and was thus insufficient for wintering. Some hundred penguins were killed to supply us with fresh meat, and seal blubber was used as fuel.

The winter passed without accident, but with a complete lack of intellectual employment. On September 29 we started again for the station on Snow Hill, were stopped for three days in a violent snow-storm, and then went on slowly in unsettled weather. On October 12, traveling along the coast of the above-mentioned island, we, by a strange coincidence, unexpectedly met with Nordenskiöld, who had reached this region through a large interior channel just then discovered by him. Loading our effects upon his dog sledge, we continued the journey pleasantly through Sidney Herbert Sound and outside Mount Haddington. After four days' traveling in splendid weather, we reached Snow Hill on October 16.

Our sledge party was dispatched from the *Antarctic* to fulfill a duty that we failed to carry out in face of natural obstacles which we could not master. The scientific results of our undertaking are very limited. Living during the winter in a misery of dirt and darkness, and wanting also the simplest instruments, we were unable to make any kind of observations. Still, our time was not spent totally in vain. We entered a virgin area, where Duse made a survey that forms a necessary link between his chart of the Orleans Channel and the extensive cartographical work executed by Nordenskiöld and Duse together farther south on the east coast.

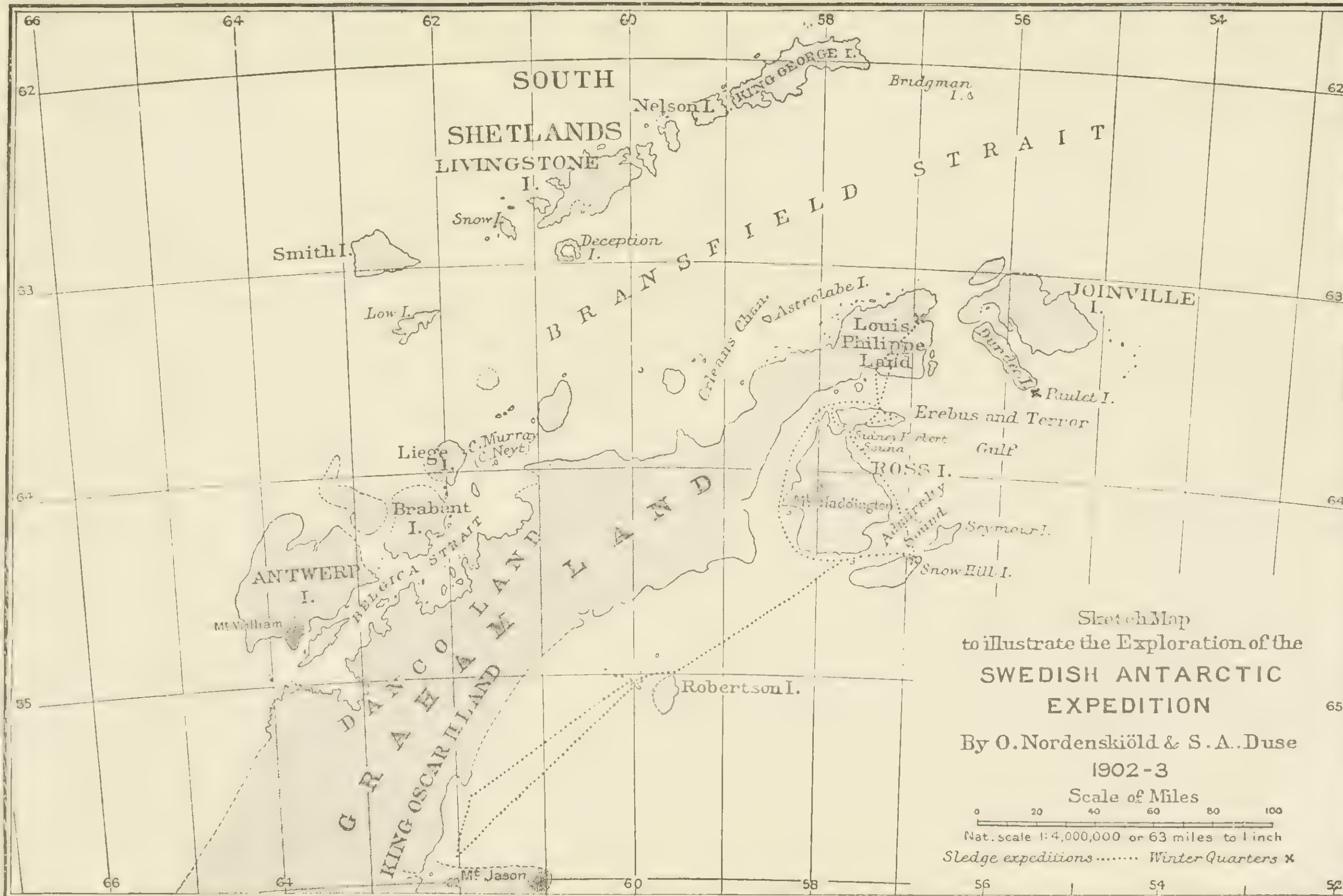
In the Orleans Channel I collected some facts, adding to the evidence brought forward by Mr. Arçtowski, and proving that the large channel was once filled by an immense glacier moving in a northeast direction. Near to our wintering place I found some other and very striking traces of an earlier wider extension of the glaciers. This material will soon be published, in combination with my observations from South Georgia, the Falkland Islands, and Tierra del Fuego.

On the geological survey of the vicinity of the bay where we wintered, I made another noticeable find—well-preserved plant fossils, cycadas, conifers, and ferns, a flora of apparently Lower Mesozoic age. A small selection of this material was brought with us on the sledge to Snow Hill, but the great mass was left at our winter place, and afterwards picked up by the Argentine relief ship.

Our involuntary wintering brought also a certain practical result. By force of circumstances, living principally on the products of surrounding nature, and, like Nansen and Johansen in Franz Josef Land, in many respects following the mode of life of the Eskimo, we, together with the party wintering on Paulet Island, accumulated an

experience, new for the Antarctic regions, which, when once fully described, might be of service to future explorers in distress during the survey of the desolate and stormy southern lands.

To me it was of special interest to get intimate around our wintering place with a nature so different from the now well-surveyed region round the station on Snow Hill. Instead of its unfolded table-land surrounded by a shallow sea, we have here a deep sound with fjord-like bays swarming with a rich fauna, and a land with numerous edged nunataks rising through the inland ice—a folded region with such a variety of sedimentary and eruptive rocks that the find of a rich Mesozoic flora is only to be regarded as a first hint of the possibilities of a future more extensive exploration. In the lonely winter months I sometimes amused myself with sketching in detail a survey of the geology and biology of this region—a plan that, I hope, will not wait long for its realization.


SOUTH SHETLANDS
LIVINGSTONE I.
KING GEORGE I.
Nelson I.
Bridgman I.
Snow I.
Smith I.
Deception I.
Low I.
BRANSFIELD STRAIT
Orleans Chan.
Astrolabe I.
Louis Philippe Land
JOINVILLE I.
Dundee I.
Paulet I.
Erebus and Terror Gulf
ROSS I.
Admiralty Sound
Seymour I.
Snow Hill I.
Liege I.
C. Murray
(C. Neyt)
Brabant I.
BELGICA STRAIT
ANTWERP I.
Mt. William
DANCO LAND
GRAHAM LAND
KING OSCAR II LAND
Robertson I.
Mt. Jason
Sketch Map
to illustrate the Exploration of the
SWEDISH ANTARCTIC
EXPEDITION
By O. Nordenskiöld & S. A. Duse
1902-3
Scale of Miles
0 20 40 60 80 100
Nat. scale 1:4,000,000 or 63 miles to 1 inch
Sledge expeditions .... Winter Quarters ×

FOOD PLANTS OF ANCIENT AMERICA.[a]

By O. F. Cook,
U. S. Department of Agriculture.

Agricultural science so generally appears as a borrower from physics, chemistry, botany, or zoology that it has not been expected to furnish facts of use in other lines of investigation. Thus, although it has been known since the sixteenth century that the same primitive food plants were cultivated throughout the tropics of both hemispheres, the significance of this remains unappreciated, and there is still doubt and speculation regarding prehistoric communication across the Pacific. Alaskan land connection, Buddhist missionaries, stranded Japanese junks, and other possibilities of a northwestern contact have been gravely and minutely discussed, while unequivocal evidence of tropical intercourse lay only too obviously at hand. The cultivation of the same seedless plants, such as the yam, sweet potato, taro, sugar cane, and banana by the primitive peoples of the islands of the Pacific, as well as by those of the adjacent shores of Asia and America, indicates, with attendant facts, not only an older communication but an intimate contact or community of origin of the agricultural civilizations of the lands bordering upon the Pacific and Indian oceans. Concrete biological data need not be disregarded because the peopling of America by the lost tribes of Israel and other equally fanciful conjectures are discredited.

THE CULTIVATED PLANTS OF THE PACIFIC ISLANDS.

Notwithstanding the immense distances by which the tropical islands of the Pacific are separated from the continents and from each other, European discoverers found them already occupied by an adventurous, sea-faring people who knew enough of the stars, trade winds, and currents to navigate their frail canoes in those vast expanses of ocean without the mariner's compass. The agriculture of the Polynesians was, however, no less wonderful than their seamanship, and was certainly not less important to them, since the coral islands of the Pacific are not only deficient in indigenous plants and animals suitable for food, but the natural conditions are distinctly unfavorable to agriculture.

[a] Revision of article on The American Origin of Agriculture, in Popular Science Monthly, October, 1902.

"The whole surface of these flat coral islands is like the clean white sanded floor of an old English kitchen. The cocoanut tree springs up everywhere, but in the spots where yams and taros are grown the sand is hollowed out and a pit formed, from 100 to 200 yards long and of varying width, into which decaying cocoanut leaves and refuse are thrown till a rich soil is formed."[a]

"The position occupied by the Polynesian races as tillers of the soil has hardly had sufficient attention given to it, although it may be doubted whether any people ignorant of the uses of the metals ever advanced so far as they have done. * * * Let any one read the account given by the first visitors to New Zealand—especially Cook—respecting the Maori cultivations of those days—the care that was taken to keep them free from weeds; the labor expended in conveying gravel to hill up the kumara plantations; the trouble taken to protect them from the strong winds by means of temporary screens or fences; the months employed in building houses (often highly carved and decorated) in which to store their crops; the amount of patient care and selection required in raising new varieties."[b]

The agricultural achievements of the Polynesians become even more impressive when we reflect that so many of their cultivated species were not propagated from seeds but from cuttings. These must have been carefully packed, kept moist with fresh water, and protected against the salt spray, to survive the long voyages in open canoes. A list of 24 species of plants believed to have been brought to the Hawaiian Islands by prehistoric colonists is given by Hillebrand.[c] This number, however, must be greatly increased, since there were many varieties of the sweet potato, taro, sugar cane, and banana. Moreover, the Hawaiian group is scarcely more than subtropical in climate, and lacks numerous seedless sorts of the breadfruit, yam, taro, and other plants of the equatorial belt of islands, so that a complete enumeration of the species and varieties carried about by the early Polynesians among the islands of the Pacific would include nearly 100.

There are many indications to be drawn from the people themselves, as well as from the abundance of ancient ruins, that the archipelagoes

[a] Moresby, Discoveries and Surveys of New Guinea, p. 73, London, 1876. The volcanic islands of Polynesia have, of course, rich soil, but they shared the deficiency of native food plants, so that nonagricultural people could scarcely have secured a permanent food supply.

It is certain, moreover, that among the Polynesians the cocoanut is a cultivated plant no less than the yam, taro, sweet potato, sugar cane, banana, breadfruit, and numerous other species found in use throughout the tropical islands of the Pacific. An especial interest attaches to the cocoanut in that there are adequate botanical reasons for believing that it originated in America, the home of all related palms. See The Origin and Distribution of the Cocoa Palm, Contributions from the U. S. National Herbarium, Vol. VII, No. 2, Washington, 1901.

[b] Cheeseman, Trans. New Zealand Inst., 33:307–308. 1901.

[c] Flora of the Hawaiian Islands, Introd., p. xvi, 1888.

of the Pacific were the scene of a former civilization much more advanced than that found by Europeans. Seamanship, like other arts, had declined, and communication with the remoter islands like Hawaii, Easter Island, and New Zealand had been interrupted for several centuries, perhaps as a result of an intermixture of the so-called Melanesians, the native black race of New Guinea and neighboring islands of the western Pacific, peoples inferior in agriculture, seamanship, and social organization. In spite of the richer native flora of the Melanesian islands, no cultivated plant of importance seems to have been domesticated there, no species being reported as in cultivation among the Papuans which is not shared with the Malays to the west or with the Polynesians to the east, and in nearly all cases with both.

The primitive agriculture of all the Pacific islands may be viewed, then, as a connected whole, and a detailed study of the origins, present distributions, native names, agricultural methods, and domestic uses of the numerous species and varieties of cultivated plants may be expected to yield the most definite information now obtainable regarding the origins and migrations of the ancient agricultural peoples of the Tropics.[a] At present we have only incomplete and scattered data collected incidentally by missionaries, travelers, and professional botanists who did not appreciate their opportunities from the agricultural point of view. But even these miscellaneous facts are often of unexpected interest. Thus, we know that in Central America the use of leguminous shade trees in cacao plantations was adopted by the Spanish colonists from the natives, who furnished even the name, "mother of cacao," by which the species of *Erythrina* and other leguminous shade trees are still known in Spanish America. The Indians, of course, were not aware that the roots of the leguminosæ developed tubercles for the accommodation of bacteria able to fix atmospheric nitrogen in the soil, and thus increase its fertility. They believed that the "madre de cacao" supplied water to the roots of the cacao, a fanciful idea still credited by many planters, and not much improved upon by the current notion that shade of large trees is beneficial to cacao and coffee. In the Pacific we encounter a similar fact with reference to the yam bean (*Pachyrhizus*), a leguminous vine with a fleshy edible root. The natives of the Tonga Islands no longer cultivate *Pachyrhizus* for food, but they nevertheless encourage its growth in their fallow clearings in the belief that it renders them the sooner capable of yielding larger crops of yams. Such anticipations of the results of modern agricultural science are of extreme interest, but it is still uncertain whether similar knowledge exists in other archipelagos of the Pacific, or on the American continent where *Pachyrhizus*

[a] Even the cosmopolitan tropical weeds are worthy of careful study from this standpoint. After excluding aquatic, swamp-land, and strand species, Seeman found 64 genuine weeds in Fiji, of which 48 were common to America, while only 16 were held to be Old World species.

probably originated. The botanists report it as "a common weed in cultivated grounds," and we learn further that, in the absence of better material, the people of Fiji use the fiber for fish lines, and that the plant sometimes figures in an unexplained manner in their religious ceremonies, an indication of greater importance in ancient times.

Our knowledge is far from complete regarding even the present distribution of the principal tropical food plants, but the need of further investigation should not obscure the striking fact that several of the food plants with which the Spaniards became acquainted in the West Indies were also staple crops on the islands and shores of the Pacific and Indian Oceans, and even across tropical Africa.

How this very ancient agricultural unity of the Tropics came about may be unexplainable by history or tradition, but it is scarcely more mysterious than that so significant a fact should have been disregarded so long in studies of primitive man. Our attitude, even yet, seems to be that of the mediæval Europeans, who believed with Columbus that the newly discovered "Indies" of the western Atlantic were the same as those of eastern Asia. Nearly a century elapsed between the discovery of America and the realization that it was indeed a new world and not merely an eastern prolongation of Asia, so that the community of food plants in regions separated by more than half the circumference of the globe did not at first appear remarkable. Modern geography has proved the remoteness of the localities, but modern biology gives no less definite testimony that the same plant does not originate twice, and makes it plain that varieties dependent everywhere for their very existence on human care must also have been distributed by human agency.

THE AGRICULTURE OF ANCIENT AMERICA.

The most important food plants of the Polynesians were seven in number—the taro, yam[a], sweet potato, sugar cane, banana, breadfruit, and cocoanut—of which six, or all except the breadfruit, existed in pre-Spanish America, and of these, five, or all except the cocoanut, were propagated only from cuttings.

Except with the banana, botany gives us much evidence for and none against the New World origin of the food plants shared by ancient America with Polynesia and the tropics of the Old World,

[a] Numerous species of true yams (*Dioscorea*) are cultivated, and the roots of many wild species are collected for food in various parts of the Tropics. The present reference is to *D. alata*, the most widely distributed of the domesticated species and not known in the wild state.

"The Haitian name of the *Dioscorea alata* is *axes* or *ajes*. It is under this denomination that Columbus describes the *igname* in the account of his first voyage; and it is also that which it had in the times of Garcilasso, Acosta, and Oviedo, who have very well indicated the characters by which the *axes* are distinguished from *batates*."—Humboldt, Kingdom of New Spain, vol. 2, p. 355. Trans. by Black, New York, 1811.

though few of them are known under conditions which warrant a belief that they now exist anywhere in a truly wild state. The partial or complete seedlessness attained by several of the important species also indicates dependence upon human assistance in propagation for a very long period of time, and precludes all rational doubt that their wide dissemination was accomplished through the direct agency of primitive man.

Ethnologists will not deny that in the Old World this distribution was the work of the remote ancestors of the Polynesians, traces of whose presence have been found distributed over the area included between Hawaii, Easter Island, New Zealand, Formosa, Malaya, Madagascar, and even across the African continent.[a] We have not been provided, however, with any explanation of the existence of these food plants in America, for ethnologists do not admit that the eastward migrations of the Polynesians reached this continent, but hold that the tribes, languages, customs, and arts of the American Indians are of truly indigenous development, not imported from Asia or elsewhere, as so frequently and variously conjectured.

"I maintain, therefore, in conclusion, that up to the present time there has not been shown a single dialect, not an art nor an institution, not a myth or religous rite, not a domesticated plant or animal, not a tool, weapon, game, or symbol, in use in America at the time of the discovery, which had previously been imported from Asia or from any continent of the Old World."[b]

If this conclusion be adopted it is obvious that the food plants common to the two hemispheres must have been derived from America. This alternative seems not to have been canvassed with the standpoint and methods of modern ethnology, but it is safe to say that in Asia no

[a] Frobenius, Zeitsch. der Gesellsch. für Erdkunde zu Berlin, Bd. 33, 1898. Report of the Smithsonian Institution for 1898, pp. 637–650.

[b] Brinton, D. G., in Memoirs of the International Congress of Anthropology, p. 151, Chicago, 1894. The same argument has been stated somewhat less radically by Payne, but with no more adequate appreciation of the significance of the facts of tropical agriculture:

"If advancement was at some remote time imported from the Old World into the New, how happens it that at the discovery all the domesticated animals and nearly all the cultivated food plants of the Old World were either wanting or existed only in a wild state in the New World? * * * Pulse [the bean] was the only cultivated plant common to America and the Old World. * * * Civilized immigrants from Asia would naturally strike the New World in British Columbia or Oregon; and the doctrine of imported advancement finds its most decisive refutation in the fact that from the most remote until recent times agriculture was here absolutely unknown." Payne, Hist. of the New World called America, Vol. II, p. 340–347.

It is possible that there were no Old World cultivated plants in America except the banana, which evidently arrived late. That Asiatic agriculture was not introduced into America is, however, far from proving that American agriculture was not introduced into Asia.

such arguments can be made as in America against the exotic origin of the earliest civilizations. It is a simple zoological fact, also freely admitted by ethnologists, that the straight-haired Malayoid peoples are not the original inhabitants of southeastern Asia and the neighboring islands, since throughout these regions there are isolated remnants and traces of earlier curl-haired types, such as the Negritos, Andamanese, Papuans and Ainus.[a]

If it be reasonable to suppose that the food plants which the Polynesians shared with the tropical peoples of both continents were carried by them across the Pacific, it is also reasonable to seek the origin of these widely distributed species on the continent which gives evidence of the oldest and most extensive agricultural activity, and to the question in this form there can be but one answer. The agriculture of the Old World tropics is adequately explainable by the supposition that it was brought by the Polynesians, since the root crops of the Polynesians were also staples of the Old World tropics. This proposition would not apply to America, where, in addition to the sweet potato, yams, yam-bean (*Pachyrhizus*), canna and taro, which crossed the Pacific, the aborigines also domesticated a long series of root crops confined to America at the time of its discovery. Such are: *Manihot* (cassava), *Maranta* (arrowroot), *Calathea* (lleren), *Solanum* (Irish potato), *Xanthosoma* (several species), *Oxalis* (oca), *Sechium* (chayote), *Tropæolum*, (massua[b]), *Ullucus*, *Arracacia*, and *Helianthus* (Jerusalem artichoke)[c] all of considerable local importance.

The simplest of cultural methods, propagation from cuttings, was applied to these root crops and has been in use for so long a period that several of them have become seedless. With equal uniformity the distinctively Old World root crops are grown from seed. And as all the Asiatic and European species are of temperate origin and have not been greatly modified from their wild ancestral types, it is reasonable to believe that they were domesticated by peoples already accustomed to the planting of cereals, which are correctly viewed as the basis of temperate agriculture. Root crops of American origin belong to at least twelve natural families, and the only important Old World addition to the series is the mustard family, a distinctly temperate group, the cultivated members of which have not been greatly modified in domestication, and are still known in the wild state.

This apparent superfluity of American root crops is explainable by the fact the different plants were independently domesticated in differ-

[a] Science, N. S., 15: 928–932. 1902.

[b] Mr. W. E. Safford notes that the word "māsoā" means, in the Samoan language, sticky or starchy and is applied to the Polynesian arrowroot (*Tacca pinnatifida*) a root crop of the Pacific islands. See Pratt, Samoan Dictionary, p. 211, 1893.

[c] All these root crops were propagated from cuttings except *Pachyrhizus*, *Canna*, and *Sechium*. Other seed-grown cultivated plants common to the two hemispheres were the cocoanut, bean, cotton, gourd (*Cucurbita*), and bottle gourd (*Lagenaria*).

ent localities, which means also that conditions favorable to the development of agriculture were very general among the natives of America. That most of these plants are not known in the wild state testifies also to the great antiquity of this agricultural tendency, while archæology shows the same antiquity and diversity of prehistoric civilizations in America. From the mounds of Ohio to the equally remarkable ruins of Patagonia, the American continents and islands are, as it were, dotted with remains of rudimentary civilizations which must have required centuries and millenniums to rise from surrounding savagery, culminate, and perish. The constructive arts by which the existence of these vanished peoples is made known took the most diverse forms; some made mounds, some expended their energies upon huge carvings on high, inaccessible rocks, some dug devious underground passages, some set up monoliths and carved statues, and some built massive platforms, terraces, pyramids, temples, and tombs, while still others are known only from their pottery or their metal work. In civilization, as in agriculture, the tropics of America stand in striking contrast to those of the Old World. Here men of the same race showed great diversity of plants and arts; there races are diverse, while arts and staple food plants are relatively little varied. The early civilizations of the eastern world resembled some of the primitive cultures of America more than these resembled each other.

The American origin of agriculture is thus not doubtful, since not merely one, but several, agricultures originated in America. The same can not be claimed for Asia and Africa, where only root crops shared with America attained a wide distribution, an indication that they reached those continents before the uses of the similar indigenous plants had been discovered.

POISONOUS ROOT CROPS.

The domestication of so many root crops in America indicates, as has been intimated, a widespread use of food of this kind before agriculture began, and many savage tribes still have recourse to wild roots, either as a staple article of diet, or in times of scarcity. It is evident, however, that the culture of the principal root crops of America was not begun as a simple and direct transition from the use of fruits, which are commonly supposed to have been the food of primitive man. The more ancient and more important of the Old World root crops, the onions, leeks, garlics, carrots, and radishes are eaten, or are at least edible, in the raw state, but in America there seems to be no indication that the natives used any root crop in this way. Some of them, such as the sweet potato, the artichoke and the "sweet cassava," can be eaten raw, but throughout the tropics of America the Indians, like the Chinese, prefer everything cooked. This habit must have been

adopted very far back to make possible the ancient domestication of *Manihot* (cassava), *Colocasia* (taro) and *Xanthosoma* (yautia), since the fleshy underground parts of these plants contain substances distinctly deleterious and extremely unpalatable until disintegrated and rendered harmless and tasteless by heat. The same may have been true of the sweet potato,[a] since the fleshy roots of its uncultivated relatives are strongly purgative. Several of the yams, both wild and cultivated, are also poisonous in the raw state.

That these poisonous root crops were the most popular, widespread and ancient would seem to afford sufficient proof that the discovery of the use of fire in cooking preceded the development of the art of agriculture, though further support may be derived from the very practical consideration that without fire the primitive savage with his stone ax would make little headway in the work of clearing away the forest, which is everywhere the first preliminary of tropical agriculture.

To be able to utilize as nourishing food the natural supplies of starchy roots, which to other tribes were poisonous, would give the primitive fire users an important advantage over their neighbors, and would greatly conduce to the adoption of a settled existence in districts where the plants were plentiful. Cassava, yams, taro, sweet potatoes, and others of the primitive series of root crops often grow freely and without care from rejected fragments or pieces of stem, so that the digging of the roots and trampling down of the vegetation would not exterminate the wild supply, but would afford, on the contrary, abundant opportunity and encouragement for the gradual increase of cultural efforts.

A third important step in the domestic economy of primitive man was the making of dry meal or starch from roots, accomplished in the tropics of both hemispheres by similar processes of grating, soaking in water, boiling, or treating with alkalis to destroy their poisonous properties. Separated from the sugars and other readily soluble sub-

[a] A plant which may be the wild ancestral form of the sweet potato is a common weed in the Coban coffee district of eastern Guatemala. The absence of the sweet potato from Samoa, Fiji, Guam, and the Philippines may have inclined some to doubt its prehistoric distribution in the Old World west of Hawaii and New Zealand, but according to Bretschneider it is recorded in Chinese books of the second or third century of the Christian era, and there are many varieties with native names in tropical Africa, both east and west, and legends indicative of its presence in early times.

"It is told me as truth, that before the Portuguese came to this coast (Guinea), the negroes subsisted themselves with these two fruits (yams and sweet potatoes) and a few roots of trees, they being then utterly ignorant of Milhio (maize), which was brought hither by that nation." (Bosman's Guinea (1698) in Pinkerton's Voyages, vol. 16, p. 459.)

Cheeseman records two varieties of the sweet potato as existing in Rarotonga before the arrival of Europeans, and believes that the plant has been cultivated there "from time immemorial." (Trans. Linn. Soc. Lond., 2 ser., 6:289, 1903.)

stances which retain or absorb moisture, the starch of the taro, cassava, arrowroot, canna, and other root crops can be quickly and thoroughly dried, and will then keep indefinitely. In the absence of cereals this simple expedient might well be deemed an epoch-making discovery, since it rendered possible the accumulation of a permanent, readily transportable, food supply, and thus protected man from the vicissitudes of the season and the chase. That the resulting economic difference appeared striking to the hunting tribes of Guiana is apparent in the name they gave to their agricultural neighbors, whom they called "Arawacks" or "eaters of meal."

Cassava in the raw state carries a deadly charge of prussic acid and begins to decay in a few hours after being taken from the ground, but properly prepared it furnishes the starch which keeps best, and which in the form of tapioca our civilization is tardily learning to appreciate as a wholesome delicacy. In spite of its unpromising qualities when raw, cassava seems to have been the first and only root crop used by many South American tribes who plant nothing else except the so-called peach palm (*Guilielma*), a species which gives suggestive evidence of a cultivation much older than that of the date palm, since it is generally seedless, and is not known in the wild state. The farinaceous fruits are made into meal and baked into cakes in the same manner as the cassava, to which recourse is necessary during the months in which the single harvest of palm fruits is exhausted.[a]

Cassava is, indeed, so distinctively the best, as well as the most generously and continuously productive, of the tropical root crops, that it could hardly have been known in the regions in which the others were domesticated. Ever since the Spanish conquest put an end to the isolation of the native peoples of tropical America the use of cassava has been slowly extending at the expense of similar crops; it has also found a footing in the Malay region and other parts of the East.

THE DOMESTICATION OF THE BANANA.

In further support of the suggestion that the use of the starch-producing root crops is a distinctively American development of primitive agriculture is the fact that the tropics of the Old World contributed no important cultivated plant of this class, and none which give evidence of long domestication. On the other hand, such regions as Madagascar and East Africa, where Polynesians are now supposed by ethnologists to have settled in "remote prehistoric times," continued

[a] Some of these tribes are extremely primitive and, in the absence of all domestic implements, grate their cassava on the exposed spiny roots of another native palm (*Iriartea exorhiza*). Some Indian tribes of Guiana are similarly dependent upon still a third palm (*Mauritia*), from the pith of which they secure starch in a manner strongly suggestive of that used with the sago palm of the Malay region.

the culture and differentiation of the varieties of the taro and the sweet potato, and were agriculturally mere outposts of the American tropics.

The presence of the banana might be thought to explain the relatively small importance of root crops in the Old World, since it furnishes with far less effort of cultivation and preparation a highly nutritious and palatable food. It appears, however, that the use of root crops must have preceded the domestication of the banana, for, although the seed-bearing wild bananas are worthless as fruits and hence would not have been domesticated as such, nevertheless more species of them than of any other genus of food plants were brought into cultivation. The clue to this paradox is afforded by the fact that bananas are still cultivated as root crops in the Old World tropics, particularly in New Caledonia and Abyssinia.[a]

That the varieties used like vegetables or root crops are as old or older than those grown for fruit is indicated by the fact that, like the sweet potato, taro, sugar cane, and ginger, they seldom produce flowers. Furthermore, among all savage tribes the varieties valued by civilized peoples as fruits are relatively little used, far greater popularity being enjoyed by the so-called "plantains," not edible in the raw state, even when ripe, though nearly always cooked and eaten while still immature, or before the starch has changed to sugar. They are also in many countries dried and made into a meal or flour often compared to arrowroot.

In dietary and culinary senses the breadfruit also is as much a vegetable as the taro or the sweet potato; as a fruit it would be no more likely to be domesticated than its distant relative, the osage orange. The farinaceous character of the breadfruit also probably explains its relatively greater importance among the Polynesians than in its original Malayan home, as shown by the propagation of numerous seedless varieties. The popularity of the breadfruit among the Polynesians was

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[a]The suggestion that the primitive culture race which domesticated the banana came from America also receives definite support from the fact that an American plant (*Heliconia bihai*), somewhat similar to the banana but without an edible fruit, reached the islands of the Pacific in prehistoric times. Though no longer cultivated by the Polynesians, it has become established in the mountains of Samoa and in many of the more western archipelagoes. In New Caledonia the tough leaves are still woven into hats, but the *Pandanus*, native in the Malay region, affords a better material for general purposes and has displaced *Heliconia* in cultivation among the Polynesians. In the time of Oviedo the natives of the West Indies made hats, mats, baskets, and thatch from the leaves of *Heliconia*, and the starchy rootstocks were eaten.

Professor Schumann, of Berlin, has recently recognized the prehistoric introduction of *Heliconia bihai* from America to the Pacific Islands.

"Originally native in tropical America, but extensively naturalized since very ancient times (*uralten Zeiten*) in Polynesia and Malaysia." (Schumann und Lauterbach, Die Flora der Deutschen Schutzgebiete in der Sudsee, 224, 1901.)

further extended by the discovery that the fruits could be stored in covered pits, the prototypes of the modern silo.

In Abyssinia the tender heart of the banana, there cultivated as a root crop, is fermented in a similar manner and then baked into cakes.[a]

FROM ROOT CROPS TO CEREALS.

If the domestication of the banana is to be ascribed to cultivators of root crops, the same reasoning applies with even greater propriety to cereals. Tribes accustomed to subsist on mangoes, dates, figs, or similar fruits which require no grating, grinding, or cooking, and are eaten alone and not with meat, would not develop the food habits and culinary arts necessary to equip primitive man for utilizing the cereals.

Wild bananas and their botanical relatives are natives of the rocky slopes of mountainous regions of the moist tropics, where shrubs and trees prevent the growth of ordinary herbaceous vegetation. The commencement of the culture of cereals by fruit-eating natives of such forest-covered regions is obviously improbable, but would be a comparatively easy transition for the meal-eating cultivators of root crops, since the grasses and other plants domesticated for their seeds are exactly those which flourish in cleared ground and are prompt to take advantage of the cultural efforts intended for other crops. Thus the Japanese have by selection secured a useful cereal from the common barnyard grass (*Panicum crus-galli*), just as they have made a root crop of the burdock. Accordingly, we should look to some taro-growing tribe of southeastern Asia as the probable domesticators of rice, sesame, and Guinea corn. That root crops preceded cereals in America was inferred above partly from the fact that root crops were not there grown from seeds, and there is a corresponding indication that the knowledge of cereals preceded the domestication of the seed-grown temperate root crops of the Old World, since none of these is anywhere dried, made into starch, or otherwise prepared for storage as the basis of a permanent food supply of primitive tribes.

Without the winter protection which primitive man could not supply, the culture of cassava and other tropical root crops is confined to strictly tropical climates, so that increase of latitude and altitude would bring to starch-eating peoples the necessity of a change of food plants. Indeed, altitude seems to have played a larger part than latitude in this transformation which brought about the adoption by primitive American peoples of Indian corn, "Irish" potato, arracacha, oca, and other crops of the temperate plateaus of South America.

Without reasonable doubt, maize is the oldest of cereals. The large soft kernels which distinguish it from all other food grasses would render it easily available among the meal-eating aborigines of America.

[a] Warburg, in Engler, Deutsch Ost-Africa, Nutzpflanzen, 100. 1895. In the lake regions of Central Africa the rootstocks of the fruit-bearing varieties of the banana are also pounded, dried, and made into meal, especially in times of scarcity.

and everywhere in tropical America maize is still prepared for food by methods adapted to root crops, and not ground dry and made into bread as a cereal, as among the Europeans who have colonized America. The rough stone slab (metate) against which the primitive Indian had rubbed his cassava and other farinaceous roots to a paste served also for maize, which is first softened by soaking in water with lime or ashes. The metate and the tortilla still hold their own in tropical America.

Like other species cultivated in the highlands of tropical America most varieties of maize do not thrive in moist equatorial regions of low elevations,[a] so that it did not supplant the root crops, though having a far wider distribution than any other plant cultivated by the aborigines in pre-Spanish America. Nor did the utilization of maize mark the limit of cereal cultures in America, though no small-seeded crop of the New World compares in popularity with rice, wheat, barley, rye, and oats. Even in Mexico, the supposed home of maize, the seeds of *Amaranthus* and *Salvia* (chia) attained considerable economic importance. In addition to their use as food, the latter were made to furnish a demulcent drink and an edible oil valued as an unguent and in applying pigments, a series of functions closely parallel to those of sesame, perhaps the most ancient of Old World herbaceous seed crops. Wild seeds of many kinds were collected by the Indians of the United States and Mexico, including wild rice (*Zizania*) and *Uniola*, another rice-like, aquatic grass of the shallow shore water of the Gulf of California. In Chile there existed also several incipient cultures of small-seeded plants, such as *Madia*, while the people of the bleak plateaus of Peru and Bolivia had developed a unique cereal crop from a pigweed (*Chenopodium quinoa*), another of many evidences of a general tendency to agricultural civilization in ancient America.[b]

[a] The varieties of maize cultivated, for example, by the Indians of Guatemala and Peru are closely adapted to their different altitudes, only a few sorts yielding good crops in the tropical lowlands.

[b] "It has been erroneously stated that maize was the only species of grain known to the Americans before the conquest. In Chile, according to Molina, the *mager*, a species of rye, and the *tuca*, a species of barley, were both common before the fifteenth century, and as there was neither rye nor barley in pre-Spanish America it is evident that if they were common, even after the conquest, and not European grain, they were indigenous. In Peru the bean (two or more species) and quinua were common before the conquest, for I have frequently found them in the huacas, preserved in vases of red earthenware." (Stevenson's Travels, Vol. I, pp. 336–367.)

There are, however, many indigenous species of barley (*Hordeum*) in South America, some seventeen being listed as valid in the *Index Kewensis*. It is not impossible that some of these were cultivated, or at least utilized, before the coming of the Spaniards. It might have taken very little time for such a crop to be replaced by barley brought from Europe.

Quinua, like the root crops, is inedible when raw. It contains an extremely bitter substance which has to be removed by long cooking, during which it is customary to change the water eleven or twelve times.

As long recognized by historians and ethnologists, maize was the most important factor in the material progress of ancient America, and the American civilizations remained on a much more strictly agricultural basis than those of the Old World, a fact not without practical significance to modern agriculture, since it undoubtedly conduced to the more careful selection and improvement of the many valuable plants which we owe to the ancient peoples of America. Subordinate only to maize from the agricultural standpoint was the domestication of the beans, while the materials for a developed culinary art and a varied and wholesome diet were furnished by a variety of minor products, like the Cayenne pepper, the tomato, the tree tomato (*Cyphomandra*), the pineapple, several species of the strawberry tomato (*Physalis*), the pawpaw (*Carica*), the granadilla (*Passiflora quadrangularis*), the gourd, the squash, and the peanut. American fruit trees, such as the custard apple and related species of *Annona*, the avocado (*Persea*), the sapodilla, *Mammea* and *Lucuma*, afford refreshing acids, beverages, relishes, or salads, but do not furnish substantial food like the banana. Contrary to the opinion of De Candolle there is every probability that the banana reached America from the west long before the arrival of the Spaniards, but it evidently did not come until after the agriculture and cultivated plants of America had spread into the Pacific.

NO PASTORAL PERIOD IN AMERICA.

Relying on the traditions of the peoples of western Asia and the Mediterranean region, many writers have assumed that animals were domesticated before plants, and that a pastoral stage marked the first step of primitive man from savagery toward civilization. There are, however, no indications of such a period in the agricultural history of the ancient peoples of America, nor among the "oriental" nations of the Asiatic shores of the Pacific and Indian oceans. The straight-haired men of both continents were primarily domesticators and cultivators of plants. The Chibcha people of the interior of Colombia attained a considerable degree of advancement without adopting a single domestic animal. The Peruvians and Chinese learned to use beasts of burden and animal fibers and skins, but their pastoral efforts were merely incidental to agriculture; they remained essentially vegetarians, eating little meat, other than fish, and never taking up the use of milk.

A settled agricultural existence made it practicable, however, to tame animals, and it may well be doubted whether any animal, with the possible exception of the dog, was domesticated by wandering savages. The lack of useful domestic animals in ancient America has been discussed by Payne[a] and other historians as an evidence of the

[a] History of the New World called America, Vol. II.

inferior intelligence and resourcefulness of the aboriginal peoples, but it seems that one tribe or another had domesticated all the American animals likely to be of value to civilized man; certain it is that Europeans, with three centuries of opportunity, have not added to the number or uses, or extended the range of any American animals, except the turkey and guinea pig. On the other hand, the American Indians have not failed to appreciate the superiority of the domesticated animals brought by Europeans, and the more enterprising tribes have adopted the hen, cat, pig, goat, sheep, cow, and horse. Indeed, even nonagricultural Indians of our Western States have taken kindly to the keeping of herds of sheep and cattle, and have thus assumed the pastoral state, illustrating, perhaps, the manner in which, in ancient times, domesticated animals spread more rapidly than cultivated plants from the agricultural East into the Mediterranean region.

Nomadic hunters or fruit eaters would not be likely to domesticate anything themselves, but offered the choice of plants or animals already thoroughly tamed and improved by selection, they are more likely to take the animals first as requiring a less radical change of food and habits of life. The milk and flesh of their herds would still be supplemented by the game, honey, wild fruits, and other edible plants which might be encountered in searching for pasture for their flocks, after the manner of the patriarchs of the Old Testament. Dates, figs, and other fruit trees might receive some attention from such wanderers, but the more successful they might become as shepherds the less likely they would be to take up the planting of cereals or of other herbaceous crops, which, in the absence of fences, would be appropriated by their animals before the owners could make even an initial experiment. It is accordingly significant that the origin of the agricultures and civilizations of the valleys of the Nile and Euphrates is no longer sought by ethnologists with Semitic shepherds or more northern peoples, but with a seafaring race which has been traced to southern Arabia, and whose language has been found to have analogies with the primitive Malayo-Polynesian tongue of Madagascar.[a]

OTHER INDICATIONS OF TRANS-PACIFIC COMMUNICATION.

The American origin of agriculture could ask for no more striking testimony from Old World archæology and ethnology than the recently discovered fact that the primitive culture race of Babylonia, which brought "letters, astronomy, agriculture, navigation, architecture, and

[a] Keane (Man, Past and Present, p. 250 et seq.) considers the language of Madagascar to be Polynesian rather than Malayan, and holds that the similarities between Madagascar and Arabia are not due, as has been supposed, to a recent contact during the Mohammedan period, but date back to the ancient Minæans and Sabæans, maritime peoples who had commerce with India, and who are now supposed to have worked the prehistoric mines of the South African "Ophir."

other arts," was "a short, robust people, with coarse, black hair; peaceful, industrious, and skillful husbandmen, with a surprising knowledge of irrigating processes."[a]

It is a long reach from Babylonia to tropical America, but the community of ancient food plants will prevent biologists, at least, from passing as a meaningless coincidence the fact that these early agricultural civilizations of Asia differed in no essential respect from those of our own so-called New World, not even in the physical characteristics of the people, so that the same words describe both equally well. If it be found that the same taro plant was in reality cultivated in ancient Egypt, Southern Arabia, Hindustan, Polynesia, and America, ancient human communication between these remote parts of the world is as definitely established as though coins of Alexander the Great had been dug up. It is no empty fancy, but the most direct and practical explanation of concrete facts, to believe that the robust, straight-haired race may have brought from America some of the plants they cultivated in Asia. It was among such men that agriculture, navigation, and other arts of civilization reached high development in America at a very remote period. The ancient cultures of the Old World left traces of no such infancy and gradual growth as those of America. Egypt and Babylonia arose suddenly to civilizations further advanced than those of Mexico and Peru.

That the Aztec and Inca empires were comparatively recent political organizations has caused many writers to forget that they incorporated much more ancient culture. For centuries still unnumbered the Andean region of South America supported crowded populations. On the western slopes of Peru every inch of irrigable land was cultivated—houses, towns, and cemeteries being relegated to waste places to save the precious soil. Irrigation was practiced with a skill and thoroughness unexcelled in modern times, though by methods closely duplicated in ancient Arabia, even including the boring of deep tunnels for collecting subterranean water.

To claim that the Polynesians, Malays, Phœnecians, Egyptians, Hindoos, or Chaldeans came from America would be a careless anachronism, to say the least, for the very terms of the problem place its solution far beyond the period in which these peoples, nations, and languages were differentiated. It is doubly unreasonable to expect any very close resemblance of languages or arts in the Tropics of Asia and America at the time of their discovery by Europeans, since change and diversification had continued on both sides of the Pacific. To accomplish the dissemination of the tropical food plants there was necessary only a primitive people with the skill in agriculture and navigation possessed by the Polynesians and Malays. It has long been

[a] Keane, Man, Past and Present, Cambridge, 1899.

admitted by ethnologists that the remote ancestors of these races did overrun all the Tropics of the Old World, and the latest investigations warrant the belief that they made their influence felt also along the shores of the Red Sea and the Persian Gulf, where the civilization of the Mediterranean countries was formerly thought to have originated.

It can not be declared impossible, of course, that this primeval migration from America took place at a time when there was more land in the Pacific than now, as Belt and other geologists have held that there was, some thousands of years ago, but such conjectures are rendered gratuitous in view of the highly developed seafaring talents of the inhabitants of the Pacific islands and of the adjacent shores of America, from Alaska to Tierra del Fuego. It is no farther from America to the inhabited islands of the Pacific than from Tahiti to Hawaii, a route traversed by the Polynesians.[a] In ancient, as in modern times, the sea was not a barrier, but the most open way of communication between distant regions; then, as now, the boat was the easiest means of transportation known to man. In time and labor of travel the islands of the Pacific were far nearer to Peru, for example, than many of the inland regions conquered by the Incas of Cuzco. Moreover, the Peruvians told the Spaniards of inhabited islands in the Pacific, or at least gave sailing directions which enabled Quiros to reach the Low Archipelago. There was a tradition that one of the Incas had made a voyage of two years in the Pacific and returned with black prisoners of war. Apparently, too, they told the Spaniards that the banana was brought from this quarter, for Acosta gathered from the Indians that it was not a native of America but came from "Ethiopia." These historical incidents have been overlooked or disregarded, perhaps because such possibilities as an American origin of agriculture and a trans-Pacific dissemination of food plants have not been considered by writers on primitive man. The times, routes, and methods of travel are, of course, questions to be approached by detailed studies of many kinds. For the present purposes it suffices to remember that the actual introduction of plants by human agency discounts in advance all objections on the ground of distances and difficulties of communication, and justifies the fullest use of biological or other data in tracing the origin and dissemination of agricultural civilization in the Tropics of both hemispheres.

The distribution and the uses of tropical cultivated plants support, it is true, the belief of ethnologists in the truly indigenous character of the peoples, agricultures, and civilizations of the western hemisphere, but they also testify to a very early colonization of the islands and coasts of the Pacific and Indian oceans from tropical America.

[a] The similarity of Polynesian culture to that of ancient America has been discussed at length in Lang's Polynesian Nation, Ellis's Polynesian Researches, and Rutland's History of the Pacific.

Botanical evidence makes it plain that most of the plants shared by the people of the two continents originated in America, like numerous other cultivated species which remained limited to this continent. The primitive culture peoples of the tropical regions of ancient America were accustomed to the cooking, grinding, and storing of vegetable food, and were thus prepared to appreciate and utilize the cereals by agricultural experience lacking among the fruit-eating aborigines of the Old World, where there seems to have been no tendency toward a spontaneous development of agriculture. Civilizations have nowhere developed without the assistance of the farinaceous root crops and cereals, the use and cultivation of which are habits acquired by primitive man in America and carried in remote times westward across the Pacific, together with the social organization and constructive arts which appear only in settled communities supported by the tillage of the soil.

DESERT PLANTS AS A SOURCE OF DRINKING WATER.

By Frederick V. Coville.

A stranger left alone in a desert would die of thirst, and yet there is water in all deserts, and both the native animals and the native races know how to find it. This water is gathered and stored by plants, which have built and filled their reservoirs for their own purposes, but which yield it up, when required, for the use of the animal world.

The extent of the root system in desert plants, by means of which they absorb their water from the soil, is often astonishingly great. In the Mohave Desert of California a branching cactus (*Opuntia echinocarpa*) 48 centimeters (19 inches) in height was found to have a network of roots extending over an area of ground about 5.5 meters (18 feet) in diameter.[a] The roots lay near the surface, at a depth of 5 to 10 centimeters (2 to 4 inches), a situation which enabled them to take advantage of a single substantial downpour and, before the precipitation had been again absorbed into the parched air, to suck up a supply of water sufficient, if need be, for a whole year's use. Other desert plants send their roots deep into the ground for water, and a certain shrubby species of acacia found about Tucson, Arizona, possesses, according to Professor R. H. Forbes, a double-root system, in which one series of roots spreads out horizontally, close beneath the surface, and a second series, sharply defined, goes directly downward into the soil. Such an arrangement enables the plant to seize upon water either from light precipitation or when deeply percolating under dry stream beds.

While the devices for absorption in desert plants are unusual, the mechanical contrivances by means of which these plants are enabled to retain the moisture they have absorbed are still more remarkable. Other factors being equal, the amount of water transpired, or evaporated, from a plant is proportional to the area of its green surface, which, in ordinary plants, is a foliage surface. A specimen of coffee plant (*Coffea arabica*) weighing 20.5 grams is found to have a leaf surface computed at 164,476 square millimeters, which gives a ratio of

[a] Coville, Contributions from the United States National Herbarium, Vol. IV (Botany of the Death Valley Expedition), pp. 46–7, 1893.

1 to 8,023. A specimen of bisnaga or barrel cactus (*Echinocactus emoryi*), in the conservatories of the Department of Agriculture at Washington, weighing 77,000 grams (170 pounds) and without leaves, has a green stem surface of 1,032,320 square millimeters, with a ratio of 1 to 13.4 (fig. 1). Thus for each gram of tissue the coffee plant, representing the ordinary vegetation of a humid climate, has a green surface 599 times greater than that representing a gram of tissue in the cactus; or in physiological terms, the coffee plant, other factors being equal, is provided with means for the transpiration of 600 times as much water as the cactus.

FIG. 1.—Bisnaga or barrel cactus (*Echinocactus emoryi*). One-ninth natural size.

Not only is the green surface of desert plants very much restricted in extent, but it has such a structure as greatly to reduce the amount of moisture transpired through it. The structure of an ordinary transpiration pore in a plant of humid habitat is shown in fig. 2. Through the courtesy of Dr. R. E. B. McKenney the structure of a pore of *Echinocactus emoryi* is presented for comparison (fig. 3). It is to be noted that the cuticle of the latter is excessively thickened. Beneath the epidermis is a deep layer of hypodermis with very thick walled cells and small cell cavities. It can scarcely be doubted that, except at the pores, the epidermal structure is impervious to moisture even under the extreme desiccating conditions of the desert. Beneath the minute opening of the pore is an air chamber, the lower contracted end of which is made up of the walls of the green, moist interior cells of the plant. The portion of the walls of this chamber which lie within the hypodermis, Doctor McKenney has discovered, are cutinized, so as to be impervious to moisture. The cushion of air in the chamber is therefore slowly receiving moisture at its lower end from the interior water supply of the plant and slowly giving it off into the outer air whenever the two guard cells open the narrow slit between them. The whole structure is evidently well adapted to the maintenance of a transpiration current at an exceedingly attenuated rate adapted to the plant's limited supply of moisture.

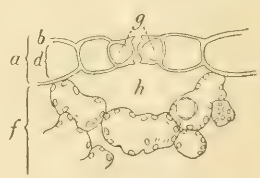


FIG. 2.—Transpiration pore of *Tradescantia virginica*. *a*, Epidermis; *b*, outer wall of epidermal cell, *d*, cavity of epidermal cell; *f*, green interior tissue; *g*, guard cells of the transpiration pore; *h*, transpiration chamber. Much enlarged. After Strasburger.

The interior of the plant consists chiefly of water-storage cells (fig. 4). These are globular in form, devoid of green coloring matter, and with walls somewhat thickened but possessing thinner sieve-plate

areas which permit the ready transfer of water from one cell to another throughout the interior. Doctor McKenney has made a determination of the water in a sample of this storage tissue and finds the astonishing amount, by weight, of 96.3 per cent. The plant when filled to its capacity is almost a tank of water.

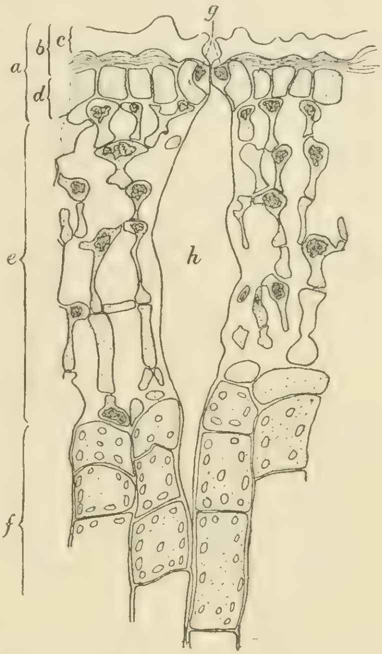


FIG. 3.—Transpiration pore of *Echinocactus emoryi*. *a*, Epidermis; *b*, outer wall of epidermal cell; *c*, cuticle; *d*, cavity of epidermal cell; *e*, hypodermis; *f*, green interior tissue; *g*, guard cells of the transpiration pore; *h*, transpiration chamber. Much enlarged. After McKenney.

That animals which live in a desert would have difficulty in securing a regular supply of water is evident. But it is a matter of fact that many of these animals go without water for months at a time, deriving all their moisture from the watery tissues of plants; and there is conclusive evidence that some animals never drink water, apparently not knowing what water is, and never eat even ordinary herbage, but subsist on dry seeds alone. D. W. Carnegie records the statement[a] that while traveling across the desert of southwestern Australia, his band of 9 camels went without water from July 29 to August 10, 1896, a period of twelve days, on the latter date taking a full drink averaging 17 gallons each; while 2 of his camels performed a still more wonderful feat of abstinence in traveling for a period of thirty-seven days, from August 22 to September 28, 1896, on only 13 gallons of water each, which they drank as follows: August 29, after seven days, 2 gallons; September 8, after ten days more, 8 gallons; September 18, after an additional ten days, 3 gallons. Bands of Merino sheep grazing on the tender annual vegetation that springs up on the desert near Phoenix, Arizona, after the winter rains, sometimes drink no water for a period of forty to sixty days. In the desert plain of Sonora, Mexico, west of the railroad station of Torres, are isolated rocky hills in which

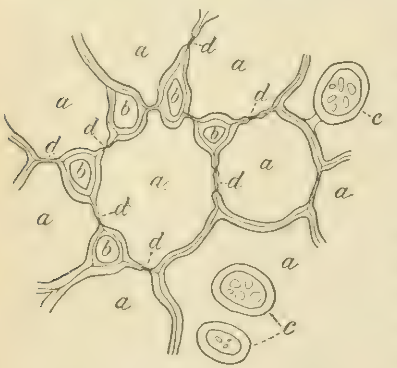


FIG. 4.—Water storage tissue of *Echinocactus emoryi*. *a*, Water-storage cells; *b*, intercellular spaces; *c*, sieve plates, face view; *d*, sieve plates, in cross section. After McKenney.

[a] D. W. Carnegie, Spinifex and Sand, pp. 194, 261. 1898.

peccaries live for months at a time without possible access to natural water. It is evident from their habit of rooting in the ground like the domestic hog, that they derive some of their requisite moisture from the underground portions of plants, while another source of moisture is the fruit of opuntia and other cactuses.

Mr. T. S. Van Dyke, in an article on the mule deer,[a] says:

When on this food [cactus] deer not only can go without water, but often go without it when it is perfectly convenient. On the great Mexican desert known as the Bolson de Mapimi, I hunted for several weeks in 1884, stopping at a railroad station 25 miles from anywhere, and known to be 25 miles from any other water. Several hundred feet from the station the leakage from the water cars of the railroad made a shallow pond some 50 feet long and a dozen wide. To the leeward of this fresh tracks of deer could be found almost any morning, all near enough to smell the water, but not one of them going to it. I had plenty of other most positive proof that the deer there, as well as the antelope, did not go to water, though the days were hot enough to make a man want water as much as in midsummer. For many a league there was no green feed except some of the varieties of cactus, and every deer and antelope that I opened in this vicinity was filled with it. The same is true in parts of Sonora and in much of Lower California.

This statement is confirmed by Mr. E. W. Nelson, the American naturalist most widely experienced in Mexican travel and observation, to whom similar instances are well known.

Various authentic records exist regarding the almost incredible abstinence of some of the small desert rodents of the southwestern United States. Mr. Vernon Bailey, of the United States Biological Survey, informs me that he kept a desert jumping mouse (*Microdipodops megacephalus*) for more than a month, during which period it ate only dry seeds and grain. After it had become very tame he placed water before it, but it would not drink. When the dish was elevated until the water touched the end of its nose, the animal showed every sign of ignorance of the liquid and even repugnance to it. Mr. F. Stephens, of Santa Ysabel, California, has recorded the statement[b] that he had a pet of the gray pocket mouse (*Perognathus fallax*) which drank no water in the six months during which it had been in his possession; that it would not touch water and did not seem to know what water was, and that it would not eat green food. He states also that Mr. W. G. Wright, of San Bernardino, California, had a captive specimen of the tuft-tailed pocket mouse (*Perognathus penicillatus*) which had no drink and no food save dry grain for more than two years. Dr. J. A. Allen, of the American Museum of Natural History, states[c] that a pocket mouse from western Texas (*Perognathus merriami*) had been kept for nearly three years without water, his food during that period consisting exclusively of dry mixed birdseed. The domicile of the animal

[a] *In* The Deer Family, by Theodore Roosevelt and others, pp. 193–194, 1902.

[b] West American Scientist, Vol. VII, p. 38, 1890.

[c] Bulletin of the American Museum of Natural History, Vol. VIII, p. 58, 1896; American Naturalist, Vol. XXXII, pp. 583–584, 1898.

was a tin box 10 by 20 by 14 inches, open at the top, but with a thick layer of earth at the bottom. Doctor Allen summarized his experience with the animal in the statement, "As no water and no fresh vegetation have been given him for nearly three years, it is evident that the only moisture required for his sustenance is derived wholly from dry birdseed." A water content determination of dry mixed birdseed, made in Washington, December 31, 1903, shows 11.75 per cent of moisture. Freshly matured wheat grains in the climate of the arid portions of California have a water content of only 6 to 8 per cent of their weight. It is impossible that these rodents, performing their functions of respiration, digestion, and secretion, can subsist on this amount of moisture. The subject is one that deserves precise quantitative measurement as well as anatomical investigation. Is it possible that these animals possess some apparatus by means of which they can abstract moisture from the air hygroscopically and condense it for their own use? Or do they manufacture the water they require by the chemical dissolution of starch?

However this may be, it is clear from some of the cases cited that the water supply of many desert animals, either for long periods or during their whole lives, comes not from natural water, but from that stored in the tissues of plants. It is an old established fact that animals do not possess the power to manufacture their food out of the raw mineral constituents of the soil, but that these constituents must first be elaborated into starch or other food products by plants. To this fundamental dependence of animal upon vegetable life may be added, in the case of many desert animals, their further complete dependence on plants for their supply of water.

Under certain conditions this dependence of desert animals upon plants for their water is extended even to the human race. The rainfall of the desert of Sonora is so small and so irregularly timed that periods of prolonged drouth occur, during which many of the customary sources of water supply, always few and far between, fail utterly. To two of the native tribes, the Seris and Papagos, such a condition is not necessarily serious, for they betake themselves to the water stored in cactuses.

Some of the largest cactuses, such as the saguaro, or giant cactus (*Cereus giganteus*), the pitahaya (*Cereus thurberi*), and the sina (*Pilocereus schottii*), are not available as a source of drinking water, for their juice is bitter and nauseating. But the juice of certain species of the genus Echinocactus, notably *E. emoryi* and *E. wislizeni*, is sweet and palatable. These cactuses, the Mexican name of which is bisnaga, are known by all natives of the desert region as a potential source of drinking water. In February, 1903, the writer, in company with Dr. D. T. MacDougal, while seeking a location for a desert botanical laboratory for the Carnegie Institution, found an opportunity to observe

the extraction of water from a bisnaga according to the primitive process and by one of the aborigines themselves. The locality was in the State of Sonora, Mexico, at a point about 12 kilometers (8 miles) west of the railroad station of Torres. Upon request a Papago Indian, the guide of the party, exhibited the operation. The cactus used was a specimen of bisnaga (*Echinocactus emoryi*) with which the region abounds.

The plant selected was about 1 meter ($3\frac{1}{3}$ feet) high and 0.5 meter (20 inches) in diameter. Its top was first sliced off, exposing the white interior (pl. I). It was evident that this was saturated with water, but the structure of the tissue was such that the water did not exude of its own accord. The Indian cut a stake of palo verde (*Parkinsonia microphylla*) about 7.5 centimeters (3 inches) in diameter at the larger and blunt end, and with this proceeded to mash the white flesh of the cactus into a pulp. As the churning progressed a bowl was formed in the top of the cactus, and when a suitable quantity of pulp had accumulated in it the Indian, taking this up handful by handful, squeezed out the water into the bowl, throwing the rejected pulp upon the ground.

From the upper 20 centimeters (about 8 inches) of the cactus about 3 liters (3 quarts) of water was obtained. Its flavor may be described as very slightly salty and somewhat herbaceous. Any really thirsty traveler would have drunk it without hesitation, and our Papago, although he had had plenty of water from the supply we carried, drank the cactus juice with evident pleasure (pl. II).

A bisnaga of approximately spherical form furnishes a more palatable water than the cylindrical specimens many years older, and care is taken to use for a masher a wood which has no bitter, resinous, or poisonous qualities. No deleterious effect is caused, our Indian stated, through drinking a quantity of the water, unless one subjects himself immediately afterwards to violent physical exercise. The natives use the cactus water, if need be, for mixing bread, and evidently it could be devoted to any camp use.

An interesting correlation is to be noted between the palatable flesh of the bisnagas and their effective protection against grazing animals through their impenetrable armor of hooked and rigid spines. Without such protection the bisnaga would be doomed to early extinction by such animals as required a continual supply of moist, herbaceous food. Other cactuses, on the contrary, which have a bitter and nauseating juice, often have only a very imperfect protection by spines, as the giant cactus (*Cereus giganteus*) and the sina (*Pilocereus schottii*). One cactus, the peyote (*Lophophora williamsii*), has no spines whatever at maturity. In appearance it is as plump and juicy as an apple; yet, as is demonstrated by its abundance in certain localities, it is amply

PAPAGO INDIAN PREPARING A BISNAGA (ECHINOCACTUS EMORYI).

PAPAGO INDIAN DRINKING FROM A BISNAGA (ECHINOCACTUS EMORYI).

protected against the depredations of animals by its bitter and poisonous juice.

Another notable feature in the mechanical construction of the bisnaga is the fluted character of its surface. Between the times when its body is fully distended with water from the absorption following a heavy rain and other times when its interior tissues are far shrunken after a prolonged drought, the plant, if ordinarily constructed, would be very liable, from the repeated wrinkling and stretching of its hard skin, to injury by cracking. What form could be more admirably suited to accommodate the bisnaga to this feature of its existence than the fluting of its surface, each fluting or rib becoming thick by the absorption of water and thin by its loss?

Strenuous are the conditions to which the plants of the desert are doomed; many and remarkable are the devices with which these conditions are met, and rich are the opportunities for research where such phenomena exist. It is a matter for congratulation that to the United States belongs the credit of first establishing a botanical laboratory in the midst of the desert. Such a laboratory has been founded near Tucson, Arizona, by the Carnegie Institution of Washington, and we may confidently expect to learn from time to time of results which shall excite our wonder and which shall constitute new contributions to the sum of human knowledge.

A NEW THEORY OF THE ORIGIN OF SPECIES.[a]

By A. Dastre.

Nearly half a century has elapsed since the appearance of Darwin's work On the Origin of Species by Means of Natural Selection. It is unnecessary to recall the commotion which that publication produced and the effects which followed. It was the signal for a profound revolution affecting the natural sciences, secondarily other sciences, and even the mental attitude of individuals. The idea of the evolution of living forms, of their descent, or rather of their transformation, already advanced by Lamarck and Geoffroy Saint-Hilaire was rescued from the oblivion or the indifference in which it had hitherto remained and was imposed, in a manner, on almost the whole scientific world. At present it is accepted with but slight opposition. It is, to be sure, only an hypothesis; but, as it is the only one that has any rational basis, it becomes, because of that fact, almost a necessity. As M. Yves Delage says:

> If there were a scientific hypothesis other than descent by which the origin of species could be explained, a number of naturalists would abandon, as insufficiently demonstrated, the opinions which they now hold.

This may be true, but there is no other scientific hypothesis, and the naturalists of to-day, willing or not, are transformists—that is to say, they are persuaded that living forms are not unrelated to each other, invariable, isolated, brought into existence by special acts of creation, and without any bond of union between them, but that they are, on the contrary, related—that is to say, derived one from the other.

Darwinism did not, however, consist merely in an affirmation of transformism, for this had already been advanced prior to Darwin. Transformism certainly arose from the application to the natural sciences of the idea of "continuity" introduced into science by the mathematicians of the eighteenth century. We may thus explain the course taken by that idea as well as the variations which it assumed. The mathematicians passed it on to Buffon, who was originally a geometrician and who entered the Academy of Sciences as such; he in turn transmitted it to Lamarck, who was one of his intimate friends, and from him it passed to Geoffroy Saint-Hilaire. It was, however,

[a] Translated from the Revue des Deux Mondes for July 1, 1903, pp. 207–219.

the illustrious English naturalist who first explained the mechanism by which, according to him, the transformation of one species into another might be effected, thus producing a continuity of living forms. This mechanism is natural selection.

Now it appears that, while Darwin succeeded in establishing the idea of the continuity of living forms by means of generation – that is to say, transformism, he was much less successful as regards the means which he proposed. To speak plainly, he failed. There are but few naturalists at the present time who attribute to natural selection any rôle whatever in the filiation of species. As has been remarked by Herbert Spencer, it is not in this way that truly specific characters can be acquired. Besides, when once acquired, they could certainly not be fixed by heredity. It is some ten years since anyone has held to the fixed heredity of characters acquired by a living being in the course of its existence, or at least during ten years past that idea, formerly admitted without opposition, has been fiercely attacked and denied by naturalists of great standing, such as Weismann, Pflüger, Naegeli, Strasburger, Kölliker, His, Ray-Lankester, Brooks, Meynert, van Bemmelen, and others.

A Dutch naturalist, Hugo de Vries, who has a wide reputation among the botanists of our time, has just given the finishing stroke to the theory of natural selection, already much shaken, and has proposed in place of it another hypothesis which he calls "the theory of mutation." The name in itself is not very significative and needs to be explained. We shall do that presently. The doctrine is founded on observation and experiments which by the sagacity, long and patient effort, and careful criticism of their author deserve to be ranked with the admirable observations of Darwin. On the other hand, it has been most favorably received by many naturalists. For these two reasons the scientific public is obliged to take it into consideration, and, at least, to become acquainted with it.

I.

Every new being resembles the ones from which it ascended, considering those in the widest sense. We say—and it is only a form of speech—that it owes this resemblance to heredity. Heredity, then, is simply the name by which we express the fact that an offspring resembles its parents. On the other hand, the resemblance is not absolute. For example, two animals of the same litter or two plants of the same sowing are never identical. We apply the term "variation," individual variation, to such divergences or to the tendency which produces them. It is, then, a fact that in new generations there appear new characters which it is impossible to attribute to a reversion to ancestral features—that is to say, they are truly new and undescribed hitherto. It is only as to the extent and importance of such characters that discussion arises.

We can not deny that variation exists. Living forms have not the rigidity of stone; they vary incessantly, and these variations have been used by breeders for the creation of races. Modifications of this kind are restricted, however, within certain limits. Their amplitude is restrained by three conditions, as follows: Generally they are not permanent and they disappear at the same time as do the circumstances under which they are produced; they are not transmissible by generation to descendants; and finally, the modified beings have not lost the aptitude of crossing with those that have not been modified. This is what is meant by declaring that these individual variations can not create a new species; for these three defects found in the modified being are exactly those which define a species.

Up to the present time no one has ever seen an animal or vegetable species engender another or transform itself into another. In other terms, no one, except perhaps Hugo de Vries, has perceived a living form arising from another form, yet differing from it by features having the value of those which distinguish species, and showing itself inapt for crossing with the parent, although capable of maintaining and preserving itself by generation. Such a profound transformation can not be accomplished in a moment or by a single effort.

Darwin supposed that such a transformation could be accomplished by degrees. According to his view the cumulative repetition of certain small variations might effect a more considerable transformation. In order to do this it would suffice that they should always be produced in the same direction during a long course of generations. Breeders effect this by reproducing and maintaining the conditions of the original transformation and breeding together the individuals which present such transformation. This is "artificial selection." It is a judicious and methodical exercise of the two properties of heredity and of variation practised for the interest and advantage of man.

The supposition of Darwin is equivalent to admitting that nature, personified, acts like man, heedful of consequences and with a method, by "natural selection" having in view the interest and advantage of species. Certain slight variations appearing under diverse influences, for example, under a change in the environment, will constitute an advantage for individuals. Such individuals are thus better adapted to these new circumstances and have a better chance of survival; these are the ones which will pair and by heredity preserve the advantageous variation, fix it, accumulate it, until there is formed a race, a variety, and finally a new species. This automatic play of the best adaptation favoring certain individuals, permitting them to survive and to reproduce themselves, has here, in natural selection, the same providential rôle as the breeder plays in artificial selection. It is the best adaptation which designs and chooses the useful variation; it is that which favors the individuals that possess it; it is that, in fine,

which degrades the others in the concurrence, either direct or indirect, which exists between animals and plants, in that sort of struggle for existence whose importance was perceived already by A. de Candolle and Lyell, and which results in the disappearance of the vanquished species and the effective triumph of the new one.

It may be noted that natural selection is not a single hypothesis; it is a linking together of three hypotheses. If we separate the links of this chain we can show that not one of them will stand test. The first hypothesis is that of the advantage in the struggle for existence which is given to an animal by the possession of a small, adaptive variation; the second is that of a preservation, by transmission, of this acquired character; the third is the progress, always in the same direction, of these profitable variations, which, accumulating, finally create a specific character. None of these hypotheses will support a searching examination.

In the first place, as to the benefit of a small, adaptive variation, it may be observed that it would be, in itself, too insignificant to give rise to selection. Let us take for example the transformation of an ungulate quadruped into a giraffe according to the Darwinian theory. In this system an increase of some centimeters in the length of the neck would be a favorable adaptive variation; it would allow the animal, in case of famine, to browse upon the verdure of trees some inches higher than his companions could. But with Mivart, Naegeli, Delage, Osborn, Emery, Cuénot, and others, we may affirm that in case of actual famine this advantage would amount to nothing and would not assure the survival of its possessor. The individuals who would die would be the youngest or the oldest, or, in a general way, the feeblest. The variation must be considerable in amount in order to constitute a real advantage and in order that the process of selection may be applied to it.

The second hypothesis is, then, to imagine that this variation, admitted, for the moment, as useful, may be preserved and transmitted by generation. We have stated above what naturalists think at the present time concerning the transmission of acquired characters. The least that one can say is that it is very much controverted.

The third hypothesis, grafted upon the first two, is the repetition of the variation. Even if we disregard the objections made to the previous hypotheses there are still others which present themselves here. It is, indeed, necessary that the variation should continue to be produced in the same direction during a great number of generations in order that it may be recognizable, since it is minute each time it occurs; many additional elongations would be needed in order to produce the neck of a giraffe from that of an ungulate. Lamarck, by placing the cause of variation in external conditions, makes this continual addition of effect plausible. The permanence, or better, the repetition of the

processes of variation, will perpetuate itself as long as these external conditions are kept up. For example, in attributing the elongation of the neck of a giraffe to the habit of browsing upon the high leaves of trees and the effort of the animal to reach those which are still higher, Lamarck accounts for the definite and sustained course of variation. But it is exactly this resource that Darwin took away, since he did not accept the ideas of his illustrious predecessor as to the causes of variation. Decidedly, selection appears to be a process more adapted for preserving a state of things than for creating a new one. It is more conservative than revolutionary.

Besides, this is not the only objection, not even the most serious one, which affects this third hypothesis of Darwin. The principal difficulty with it is that it attempts to account for the considerable change which creates a new species by too slow an accumulation of inappreciable changes. When the Darwinists are pressed closely they demand time—much time; too much time. They require indefinite series of generations in order that the smallest species may be formed. Their adversaries have reproached them with having made our globe too old; this is also the opinion of Lord Kelvin.

In reality it must be that there is not so much delay in the creation of a new species. This is exactly what Hugo de Vries contends. He denies the gradual transformation of species by the addition of inappreciable variations: or, at least, he affirms that they may be produced by a process that is rapid, precipitate, sudden. The new species whose development he has observed have arisen abruptly, as one may say, explosively. This is what the Dutch naturalist calls "spasmodic progress."

II.

The main idea of the doctrine of Hugo de Vries is the abrupt mutation of living forms. The eminent naturalist does not advance it as an a priori proposition; he deduces it from his experiments, and he is not afraid of sharply opposing it to the universal view which accepts slowly acting causes. In the course of the nineteenth century, geology was tossed from the cataclysms of Cuvier and his geological revolutions to the slow causes of gradual evolution pointed out by Sir Charles Lyell; and at the present time it is swinging back with Suess toward sudden transformations. It is interesting to note that a similar movement is occurring in biology; the attempt of de Vries is one of its manifestations.

A great number of zoologists, botanists, and paleontologists are inclined to adopt this notion of sudden changes as consonant with the teachings of experience. We may cite in this connection the well-known argument of Agassiz. This celebrated naturalist called attention to the simultaneous appearance, in the first fossiliferous strata,

of a mixed fauna comprising representations of all the grand divisions of the animal kingdom. This is shown in the Upper Silurian or Devonian horizon in which the vertebrates make their appearance in the form of fish. In the most ancient fauna, and that which has become known most recently (that of the Lower Silurian or Cambrian), all the grand divisions are still found, except that of vertebrates, each represented by quite high types. It is a question to be decided whether, lower down, in the sedimentary rocks hitherto considered as azoic, there is really a living population, more widely scattered, and reduced to the most rudimentary animals and plants—that is to say, to protophytes and protozoans, as appears from the researches of MM. Barrois, Bertrand, and Cayeux. Yet it is none the less certain that the very important remark of Agassiz is true, and that, in the Cambrian horizon, all the principal types appear simultaneously. We perceive here a sort of explosion of universal life.

In consequence of this the transformists are obliged to admit that in the short space of time that corresponds to the deposit of the most ancient fossiliferous rocks the first living beings must have undergone all the evolutions necessary for passing from the state of a simple mass of protoplasm to that of types characteristic of all the grand divisions, the vertebrates only excepted. We are authorized to conclude that the time during which the most ancient fossiliferous rocks were deposited was short, because we can judge of it from their thickness, which is much inferior to that of the subsequent strata. Therefore, but a comparatively short space of time was required for the modifications by virtue of which the first living forms produced the principal grand divisions. The Lower Silurian epoch was one of rapid transformations, of active morphogenesis, of intensive mutations. If we wished to suppose that these were caused by the Darwinian mechanism of slow accumulation of minute variations, we would be obliged to throw back the origin of life into an epoch inconceivably beyond the most ancient geologic epoch now known.

In the same way, as other paleontologists have observed, among whom is Dr. Charles A. White, the extraordinary flora of the Carboniferous epoch developed abruptly. We know nothing or but very little of the floras that preceded it. Its appearance and its extinction were sudden.

We might multiply these remarks relative to the abrupt explosions of creation in living things. Here is another. The dinosaurian lizards that abounded throughout the secondary epoch, forming, indeed, the dominant animal type, show an extreme variety taken from any point of view. There were some gigantic ones, like Brontosaurus, having a mass that was certainly equal to that of four or five elephants, others of small stature not larger than a domestic fowl. The group included carnivora and herbivora, aquatic species and

terrestrial species, quadrupeds, and bipeds quite similar to birds, except as to the faculty of flight. By the variety of their types of organization they form, as aptly stated by Frederick A. Lucas, a sort of epitome of the class of reptiles. Now, their appearance and differentiation were comparatively abrupt and sudden phenomena. It does not seem probable that they were formed by the mechanism of natural selection and that they were destroyed because of their inferiority to other species in the struggle for existence.

We arrive at similar conclusions from an examination of the first placental mammals. They appeared abruptly at the beginning of the Tertiary period; they assumed a variety of forms almost as numerous as those of the mammals of to-day, and they finally disappeared.

Besides the paleontologists, many naturalists have pointed out the existence, in animals of our own time, of abrupt variations that produce a new type that becomes fixed as soon as it appears, and that has the value of a species distinct from that from which it was derived. Mivart and Huxley, Clos, Camerano, and Bateson have called attention to the existence of such discontinuous variations, which may afford an explanation of the discontinuity of species. Yet the greater number of the examples adduced by these authors may be referred to the category of monstrosities or teratogenic variations which have succeeded in becoming fixed. This is the case with species of Asterias having numerous arms, with crinoids having three or four divisions, with a certain number of levogyrate gastropods. However, abrupt transformations have been noted by entomologists under perfectly normal conditions. Standfuss, to whom we are indebted for some extremely interesting experiments on the heredity in butterflies, speaks of "explosive transformation," thus expressing the richness in new forms suddenly produced from a single parent stock.

III.

The origin of the new theory of Hugo de Vries must be sought for in this mass of observations, facts, and theoretical ideas relative to the abrupt variation of species in opposition to the Darwinian idea of slow variation. The Dutch naturalist has, in a manner, worked over all these ideas and codified them into a coherent system. This system already existed in embryo in the well-known little work which he published in 1889 on intracellular pangenesis. His views were, at that time, purely theoretical, for he had then only just begun his experimental verifications. Since then, however, some of his experiments have succeeded in an astonishing manner. To-day, therefore, it is the views that have been scrutinized and verified which the celebrated botanist presents to the scientific public in his work on the Theory of Mutation, recently published at Leipzig.

His doctrine consists, as might be anticipated from what we have said, in the denial of gradual transformation and the affirmation of abrupt transformation. Species in general do not enjoy that perfectly uniform and monotonous existence which has been assigned to them by naturalists of the school of Linnæus and Cuvier. Paleontology teaches us that they have a commencement and an end and that, during their term, they present periods of two kinds, periods of mutation and periods of equilibrium, times of calm and times of revolution. The observation of existing species confirms this view.

Ordinarily the principal "period of mutation" is found at the earliest stage of the species, at the time of its birth, but this is not absolute. However, the phase, or the entire group of phases, of plasticity, is more or less brief in comparison with the rest of its existence. It is only at these epochs that the living being is susceptible of mutations of a specific character; it is unchangeable for the rest of the time, that is to say, during the greater part of its term. Because of this the period of plasticity or of mutation usually escapes attention and we observe the greater number of species exactly at the moment when they have become really invariable—that is to say, susceptible only of those small, secondary modifications which may, at most, conduce to the formation of varieties and races.

When, on the contrary, the species is in the period of mutation it offers an abundance of specific variations, distinct in character from the small, individual ones. They are, in fact, abrupt, clearly marked, permanent, fixed, and hereditary as soon as they appear, and the new forms are infertile when crossed on the parent stock. In a word they accomplish a transgression of the limits of a species.

Such is the new hypothesis of mutation. Before detailing the experiments on which it is founded, and furnishing the justification of its accuracy, it would be well to establish its signification, its scope, and its consequences.

This theory is a sort of rehabilitation of the idea of species. It does not, however, consider species as the fixed entity, the special and immutable category of the Creator's thought, conceived by the naturalists who followed Linnæus. It is truly a transformist doctrine; it admits the possible existence of an infinite number of species derived one from the other. Nevertheless it must not be denied that it confers on species an objective existence, a sort of reality that is foreign to the conception of the transformist school. "Species appear," says Hugo de Vries, "like invariable unities, such as are necessary in a systematic classification. Their existence is real, like that of individuals. A species is born, has a short period of youth during which it is subject to specific mutation, is maintained in an adult condition during a period which may be of great length, then finally disappears."

The doctrine of Hugo de Vries is opposed to that of Darwin in

almost every point. The Darwinian theory has for its corner stone individual variation; the new theory, specific mutation.

Individual variations are progressive, usually guided by adaptation to the environment in a direction determined by the "survival of the fittest." They are continuous—that is to say, they are produced at all periods. Mutations are quite different. They are metamorphoses, not determined by adaptation; they are produced in various ways, without any direction; they are sometimes injurious, sometimes profitable, sometimes indifferent to the individual—they appear only at certain periods of the life of the species. Besides, both of these transformations occur from the action of causes which are determinate but whose nature is unknown. The first affect, more or less profoundly, all parts of the organism; the others affect in a special way the function of reproduction. In the Darwinian theory the first form is separated from that which differs from it specifically by a long succession of generations. According to Hugo de Vries the first form which engenders another, and, ordinarily, many others, coexists side by side with this daughter species. It is only after its formation that the latter enters into competition with the species from which it sprang, and circumstances decide which shall survive and which shall disappear. Here the struggle for existence and selection suppresses species but it does not create them. In brief, the most characteristic feature of mutation is that it is a manifestation of a physiological character, connected by special conditions with the function of reproduction.

In one point only the two doctrines agree, viz, that very marked differences in organization are the effect of the disappearance of intermediate links. In the case of mutation the new form, although quite markedly distinct from the parent one, does not necessarily show great divergence from it. Its differences may sometimes be anatomically very slight, although they are physiologically very marked, since they inhibit any crossing. Great morphological divergences always result, as in the theory of Darwin, from a series of repeated mutations. These changes are, however, crowded together in a time relatively short, since newly formed species are, at the very moment of their formation, in their phase of plasticity, in their crisis of mutation.

IV.

We have now to state the evidence in favor of this doctrine and the foundations on which it rests. We may count in its favor the advantage of its reconciling the transformist hypothesis, which is necessarily logical, with the immutability of species, which is, according to de Vries, a proved fact. It succeeds in doing this, as has been seen, by supposing that there is in the life of the species a period of crisis, so to speak—a temporary period of mutation which interrupts for

a quite brief period the habitual invariability. In this it harmonizes with Darwin to a certain extent.

Hugo de Vries considers that the existence and invariability of species are facts supported by daily observation. He refers to the memorable experiments of Jordan and his followers, who made thousands upon thousands of sowings of vegetable species and never observed the passage of one into another—that is to say, a true vegetal mutation; they only obtained differences now classed under the head of individual variations. These, as is well known, are of such a nature that if we avoid artificial isolation, segregation, and selection, the forms revert to the primitive type. It is vain for transformism to deny this remarkable fixity and to replace it by an hypothesis of changes so slow, so minute, and so gradual that they become evident only after the lapse of centuries, and inevitably escape our observation at the moment.

Another fact that accords with the theory of mutation is the existence, in certain genera, of animals and plants of a great number of species that differ from each other but little anatomically. Botanists are aware that most Linnæan species are groups of living forms that are constant, hereditary, and usually infertile when crossed; that is to say, they are specifically distinct. Yet they differ so little in their aspect that many naturalists mistake them or confound them with each other. It would appear as if, at a given moment, in a crisis of mutation, the parent stock had become resolved into a multitude of secondary species which have persisted. For instance, the group of roses contains more than a hundred wild species so similar to each other that the most experienced connoisseurs make mistakes in their determinations. The thorn bushes, the willows, and the Alpine gentians are other examples of the same peculiarity, as are also the pansies and the sunflowers. In the animal kingdom many genera of insects present the same phenomena.

These, however, are merely agreements. H. de Vries has not contented himself with noting them; he has sought direct proofs of his hypothesis. The best one would be to find a plant that was actually in its period of mutation and that might beget, by means of seeds, a number of daughter plants in which there should abruptly appear the characters of a new species. We may readily apprehend the principles which would guide him in his researches. It would be necessary to experiment with genera of wild plants that have a large number of closely related species. Jordan has, indeed, established the fact that the greater number of wild species now found in Europe are specifically immutable. Yet it is possible that they may not all be so and that some may, at the present time, be undergoing a crisis of mutation. There would be more chance of finding such among the species that present a great many subspecies, this being a sign of plasticity leading

to the presumption of mutation. H. de Vries, therefore, experimented with 100 plants that satisfied this condition—centauries, asters, cynoglossi, carrots, etc. He chose seeds from those which were distinguished by some peculiarity or deviation, like fissuration of the leaves, ramification of the spines, etc. He arranged for the sequestration of the plant as soon as the peculiarity appeared, and before flowering. In order to avoid hybridization he enveloped the floral beds with bags of transparent parchment and fertilized the flower with its own pollen. The greater number of his attempts failed. Only one fully succeeded, that which related to the onagra of Lamarck, the *Oenothera lamarckiana*.

This plant is well known as the biennial onagra, or ass's herb, brought from Virginia to Europe in 1613. It is a tufted, herbaceous plant about a meter in height, with simple leaves bearing some resemblance to an ass's ear, whence the name of the plant. It has handsome flowers, usually yellow in color. Its red tap root (red rampion) is edible. Introduced into Holland, it became acclimated and is cultivated there; it also grows there in a wild or uncultivated state, escaped from gardens and from cultivation.

One species of this genus, the onagra of Lamarck (*Oenothera lamarckiana*), was especially abundant around the little city of Hilversum. Now, in 1875 it was noticed that in this district this species showed unusual vigor and a remarkable power of multiplication and dispersion. Varieties were multiplied in profusion, and there was, therefore, reason to suppose that the plant was in its plastic crisis, in its period of mutation. H. de Vries cultivated it in his experimental beds at the botanical garden of Amsterdam, not for the purpose of favoring the production of organic forms by means of culture, but because by this means such forms could be preserved, aided, protected, and given more chances of maintaining themselves. The sowings were continued and the plants were observed during a period of fourteen years, from 1886 to 1900. In 1887 a new type made its appearance. In 1888 there were already two new species. In 1900, after eight generations, H. de Vries had obtained, from 50,000 plants produced from his several sowings, 800 new individuals belonging to 7 undescribed species. There are, then, 800 individuals in 50,000 that are undergoing specific transformation. The activity of the mutation which this plant exhibits is, therefore, expressed by 1½ per cent.

The new species do not at all resemble the varieties of the parent stock. They appeared suddenly, without preliminary or intermediate forms. The care devoted to these experiments gives them a value which must attract the attention of naturalists. Their result furnishes a new and powerful argument in favor of the theory of mutation.

THE EVOLUTION OF THE HUMAN FOOT.[a]

By M. Anthony.

If it were possible for us to turn back some thousands of centuries and find ourselves, with our present form and intelligence, suddenly transported to a geologic epoch long since passed away, and into the midst of the fauna of the Middle Tertiary epoch, we would be unable to restrain our curiosity or moderate our astonishment.

We should see, gamboling and sporting upon the plains, the ancestors of our present ungulates, and we may well believe that in the deep forest shades we should encounter, together with great carnivora, beings similar to the anthropoids that live to-day in the forests of equatorial Africa and Malaysia, covered with hair, with prehensile feet, prominent mandibles, and uttering inarticulate cries.

We should doubtless pass them by without supposing that they could possibly be in any way related to ourselves.

How could we suppose, indeed, that beings so different from our present form could be the ancestors of man, whose intelligence has finally enabled him to bring under subjection the rest of the animal world?

Nevertheless, the recent progress in comparative rational anatomy, as well as in embryology and paleontology whose results continually tend to supplement and confirm those of that science, enables us to say that it is no longer absurd to suppose that our ancestors lived upon trees, that they were covered with hair, and lacked the faculty of speech. We no longer have to rely upon our imagination alone to support the doctrine that there was a common arboreal ancestor from which sprang both man and the anthropoids, and who must have immediately preceded Pithecanthropus upon the earth. Although this ancestor has not yet been placed before us by paleontological discoveries, Hæckel has, in anticipation, named it "Prothylobates." We have every reason to think that he must have been very much like existing anthropoids; similarly adapted, without doubt, to an arboreal life, in which direction the anthropoids have improved; like them, therefore, he must have had a prehensile foot and the bestial face which prominent jaws combined with a relatively small brain would give.

What necessity has intervened to cause a modification of these forms? How was the adaptation to terrestrial locomotion effected? What

[a] A Broca lecture given before the Société d'Anthropologie. Translated from the Revue Scientifique (Paris) for January 31, 1903, pp. 129–139.

course did it follow? What organ preceded the others and led to their gradual modification? Such are the questions that arise, and we may readily see that they deal with a very complex problem. The researches made during the last few years in comparative anatomy, though they may not enable us to give a final answer to these questions, at least permit us to form serious hypotheses, and I think that we are now authorized to suppose that, in the series of successive modifications, the foot and the lower limbs have played a predominant part. We may, then, according to the opinion expressed by M. Manouvrier in his remarkable studies on the Pithecanthropus, consider that the following were the successive steps of this evolution:

Impelled by a necessity whose causes we can not now determine, and which were, perhaps, due to changes in the fauna, the flora, or the climate, our ancestors must, apparently, have descended by insensible degrees from the trees and become accustomed to live on the ground. In order to effect an adaptation to this new kind of existence, the pelvic limb was naturally the first to be modified; the mobility of the toes had to be diminished, the great toe to become less and less opposable. It was also necessary that the knees should become straighter; that the movement of the joints should be amplified and, at the same time, that the distal insertions of the ischio-tibial muscles should be shifted to a higher position; it was necessary that the femur should be lengthened, should acquire force. These modifications in the pelvic limbs, which put them in advance of the rest of the organism, had at the same time the advantage, as M. Manouvrier also remarks, of allowing the thoracic limbs to become adapted in a more perfect manner to the functions of prehension and to become gradually transformed into those highly improved organs that we now possess; they also permitted the head to be raised and moved about in every direction, opening a way in brief to all the other modifications.

By this series of modifications it resulted that, at the end of the Tertiary, during the Pliocene epoch, our arboreal ancestor was transformed into an animal presenting, from certain points of view, vague resemblances to the gibbon of the present day, and which seems to be represented, according to the opinion of the most competent anatomists, by *Pithecanthropus erectus*, that form whose remains were found in Java a few years ago. Even a superficial examination of the femur of this creature shows that it was no longer a climber, but already a walker in the full sense of the term, although it must have possessed, more than the men of the present day, features of resemblance to its arboreal ancestor.

The passage from this ancestral type to man was easy, and it was probably effected either at the end of the Pliocene or the beginning of the Pleistocene.

Such seems to me to be the origin and course of the evolution of our species in its later stages.

In order to prove to you the former arboreal condition of man, by placing before you some of the vestiges of his past that he still retains, I have thought that I could not do better than to choose the comparative study of the skeleton of his foot, that organ which was so profoundly modified at the time of the transition from an arboreal to a terrestrial life, and whose modifications seem to have determined all the others. I propose to give you the results of the most recent researches.

The skeleton of man's foot contains a certain number of bones, which should be classified as follows:

Tarsus: Calcaneum, astragalus, scaphoid, first, second, and third cuneiform, cuboid.

Metatarsus: First, second, third, fourth, and fifth metatarsal.

Phalanges: Hallux (2), second digit (3), third digit (3), fourth digit (3), fifth digit (3).

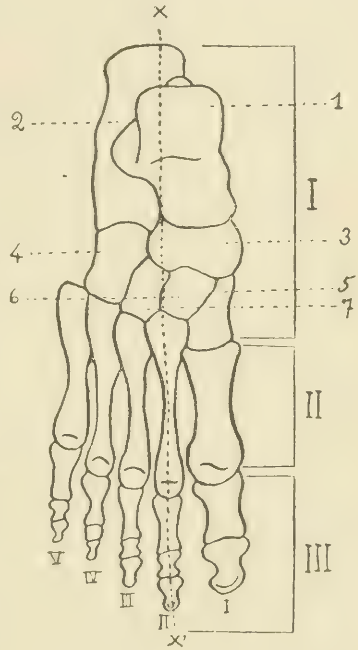


FIG. 1.—Constituent elements of the European human foot (upper surface). I, Tarsus. II, Metatarsus. III, Phalanges. I, II, III, IV, V, digital rays. 1, Astragalus; 2, Calcaneum; 3, Scaphoid; 4, cuboid; 5, 6, 7, first, second, and third cuneiform bones; XX[1], Anatomical axis of the foot.

If we follow, from the beginning of anatomical science, the work that has been done on the osteology of the foot of man and of the primates generally, we shall find that, at the end of the eighteenth century, the study of the human foot was already advanced, owing to the work of the anatomists of the middle ages and of the beginning of the modern period; the foot of the monkey, the only animal that could give us an approximate idea of our arboreal ancestors, was, on the contrary, almost unknown, and all comparison was therefore impossible. Daubenton and Camper were the first who took it up in a methodical manner, although it seems that Linnaeus, who in his celebrated classification of the animal kingdom grouped the monkeys with man in the same order of primates, had already recognized the similarities that occur between the simian foot and our own.

It was, however, with Cuvier that the era of comparative and systematic anatomical studies really opened, and in his works we begin

to find most important information regarding the foot of primates other than man.

Still, giving to the anatomical facts which he had observed a false interpretation, he thought that he was authorized to change the old Linnæan classification, disrupting the order of the primates and creating from part of it the order quadrumana, comprising the monkeys or four-handed animals, contrasting with them the bimana, comprising man, who alone is possessed of two hands and two feet.

It was an unhappy innovation, seeming to place man in a class apart from the animals that most closely resemble him and which really form with him a natural group.

After the work of Cuvier we should cite that of Meckel and De Blainville, who followed the road marked out by the master, then Vrolik, whose Treatise on the Anatomy of the Chimpanzee (1841) contains a comparative study of the foot of the higher primates.

This author gives information as to the much less solid structure of the tarsus of the anthropoids, the relative length and inclination of the astragalus, the more or less oblique direction of the articular facet of its head. He mentions, also, the special resemblance which exists between the calcaneum of the gibbon and that of man, and it is very interesting to note that he ventures to point out how defective, by reason of the confusion it creates, is the appellation quadrumanna, generally current at that time.

In 1853, Burmeister began the study of the foot of the races of man. It is about this time that a strong impulse was given to comparative anatomy by the transformation hypothesis. This naturally affected the history of the osteology of the foot, and, in 1863, Huxley, in his famous work, Man's Place in Nature, expressed very clearly his objections to the term quadrumana, and restored man to his place in the order of primates. At the same time Wyman discovered that in the human embryo the great toe, instead of being parallel to the others, makes, at a certain period of development, an angle with them, as in the monkeys, an observation which, as one may well believe, was specially calculated to break down the theory that the lower extremity of monkeys could not be compared with that of man; the same peculiarity was later noted by Leboucq.

It was at this time that our illustrious founder, Broca, published his Discourse Concerning Man and Animals. He there specially insisted on the existence, in apes, of a veritable foot, and in 1869 he treated definitely in his Order of Primates the question of the hand and the foot, finally replacing man in a position beside the anthropoids, the place which belongs to him, in spite of the arguments of Lucæ, who still thought that the denomination bimana should be preserved.

In Germany the study of the comparative anatomy of the foot was

continued, and it is worthy of note that, in 1878, Aeby showed that the astragalus of the newborn child is intermediate between that of an adult man and that of a gorilla.

Since that period the German anatomists have followed a new road. MM. Bardeleben, Pfitzner, and Thilenius have interested themselves in the study of the supplementary and accidental bones of the tarsus which the older anatomists erroneously considered as sesamoids, showing their significance by noting their presence in other types of animals, thus opening to their successors a fecund mine of new researches.

Finally, among the most recent works, there remain to be cited those of Schoffhausen, who, in 1884, studied the foot of the savage races of men; of M. Sarazin, who made remarkable studies of the foot of the Veddahs, those ancient inhabitants of the island of Ceylon, who seem, from all points of view, to be the men who most nearly approach the anthropoids of to-day; of MM. Manouvrier, Topinard, and Testut, authors of many studies of the skeletons of prehistoric men.

One of our most learned colleagues, M. Volkov, has attempted a monographic study of the skeleton of the human foot. He wished to reach a final solution of the problem, and to show how, by investigating a single organ, judiciously chosen, it would be possible to prove the arboreal habits of our ancestors, and he seems to have succeeded perfectly. His work is still unpublished, but he has been good enough to place at my disposal his manuscript and his remarkable collection of drawings and photographs, permitting me thus to give you the earliest glimpse of his work.[a] I am going to give you the results of his researches and to tell you, supporting myself on the arguments he has furnished and upon his measurements, how we should regard the human foot at the present time.

The study of the human foot, undertaken for the purpose of throwing light upon the problem of the origin of man, seems to me to be rationally divisible into three parts:

First. A part relating to comparative anatomy, in which the foot of man in general, or that of men of different races in particular, is examined and compared with that of other animals in order to determine the characters by which they resemble each other.

Second. An embryological part, in which the foot of man is examined during a period of its development in order to ascertain whether, at any particular stage, it resembles the foot of animals.

Third. A paleontological part, in which the foot of men of prehistoric races is examined in order to determine whether it possesses any

[a] All drawings reproduced here are after the photographs or sketches of M. Volkov. In the greater number of cases I have confined myself to stating the facts without giving measurements. These would not be suitable for a lecture, and, besides, M. Volkov will soon publish them in detail.

characters by which it resembles more closely the foot of animals than does the foot of existing man.

If the foot of man presents marked resemblances to a foot adapted for arboreal life, if these characters are marked among the inferior races, the fetus or the child, and prehistoric man, we have reason to think that the human foot is derived from the arboreal type. M. Volkov treats only of the comparative anatomy, merely touching upon the embryology.

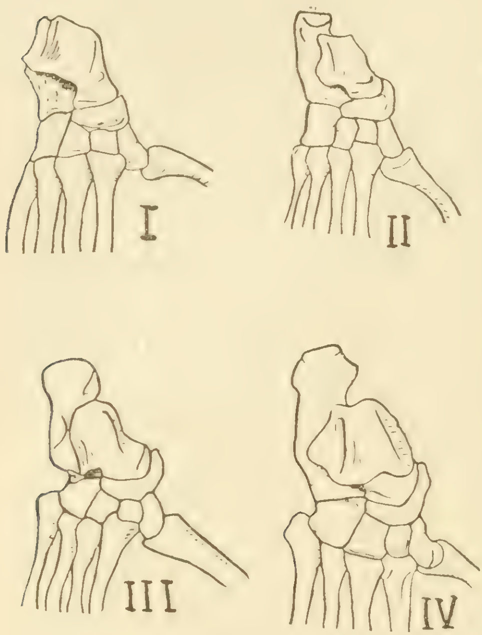


FIG. 2.—Feet of Anthropoids (upper surface).—I, Orang. II, Gibbon. III, Chimpanzee. IV, Gorilla.

The study of the human foot taken as a whole, without separating it into its component parts, furnished M. Volkov no important information relative to the history of its development.

Having established the fact that climbers have generally longer feet than walkers, which is explained very well by their being obliged to grasp branches, sometimes of large caliber, he sought to ascertain whether men of the so-called inferior races have, as might be expected, feet relatively longer than those of Europeans, thus approaching in that character an ancestral, arboreal type.

He was unable to record any positive results in this respect, the individual differences being more considerable than the differences of races.

In the same way, having noticed that the feet of arboreal living animals are narrower than those that walk, in which the base of sustentation has to be as solid as possible, he thought he might find that the foot of the inferior races was narrower than that of Europeans.

As a matter of fact, the contrary is the case, and the greatest relative width of feet occurs among the negritos, a circumstance explained by the very marked divergence of the great toe, one atavistic character masking another.

FIG. 3.—Feet of a negrito.

On the other hand, the human foot surpasses in relative height that of the arboreal animals; he found that, in this respect, the foot of the

negro occupied a position intermediate between the arched foot of the European and that of the gorilla.

M. Volkov quickly realized that a study of the foot pursued in this way would give him but meager results; without further delay he immediately undertook a separate study of the different parts, bone by bone. We will follow him in this investigation. Still, since our time is limited, I will confine myself to the consideration of the three most important elements of the tarsus—the calcaneum, the astragalus, and the scaphoid—which will enable us to clearly understand the arch which gives to the human foot its mechanical perfection and what we are accustomed to call its beauty. My method of procedure will be as follows: After having indicated to you the architectural features that characterize an adaptation to arboreal life—that is to say, the features of the simian foot—and those which characterize an adaptation to the biped and plantigrade method of walking—that is to say, those of the human foot—I shall show you in what respects the feet of new-born children and of men of the inferior races possess in a higher degree than ours traits of resemblance to the feet of arboreal animals. These traits of resemblance can only be vestiges of our past, still persisting in the lower ranks of our species and which have disappeared with us, our foot seeming to have attained the maximum of perfection for the function it is to fulfill.

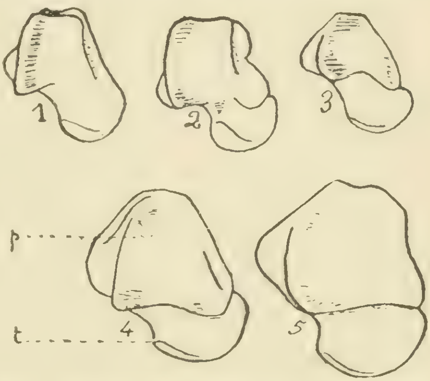


Fig. 1.—Astragali arranged so as to show the angle of divergence of the head (upper surface): 1, Cynocephali. 2, Hylobates. 3, New-born European. 4, Negrito. 5, European adult; *p*, trochlea; *t*, head.

Astragalus.—The total length of the astragalus is less in the climbers than in the walkers. In man its minimum length is found among the lower races. The same is true as regards its height.

The most important character, however, that M. Volkov has studied in the astragalus is the angle of divergence of its head. The cause of this divergence, upon which it closely depends, is evidently the same in all the pentadactylate vertebrates; it is the divergence of the first cuneiform, the first metatarsal, and the great toe, which together form a united whole. Now this divergence is, as is well known, considerable among climbers in general, and in particular among monkeys, whose feet are adapted for the function of grasping. In man, on the contrary, adapted for biped locomotion, the first toe is placed against the other toes; its mobility would impede walking, and the astragalus, instead of being movable, as in the climbers, becomes the support of

the weight of the body, the keystone of the plantar arch. The angle of divergence of the head of the astragalus is therefore but slight. The newly born and the adults of the inferior races hold in this respect a position intermediate between the gorilla and the European adult.

		Average angle in degrees.
Cebidae [a]	Ateles	52.0
	Cebus	40.0
Pitheci	Semnopithecus entellus	35.0
	Macacus cynomolgus	30.0
	Cynocephalus	30.0
	Macacus sylvanus	28.0
Anthropoids	Hylobates	36.0
	Chimpanzee	35.0
	Orang	33.0
	Gorilla	30.0
New-born Europeans		29.0
Negros ♀		24.0
Veddahs ♀		20.0
Europeans ♀		17.8

Besides its divergence, the head of the astragalus also shows a certain amount of torsion corresponding to the position of the first toe,

FIG. 5.—Astragali (anterior surface), showing the torsion of the head: 1, Maget. 2, Negrito. 3, European; *p*, trochlear surface; *t*, head.

different, consequently, in the arboreal and the walking races; and in this, too, the lower races of men hold an intermediate position.

Calcaneum.—The studies of M. Volkov relating to the calcaneum were particularly interesting. He first saw that the length of the calcaneum relative to that of the foot had a direct relation to the aptitude for walking. It is markedly shorter in the climbers than in the walkers, and among the monkeys it is those that sometimes walk, like the macaques and the cyncocephali that have the longest calcaneum. As to the anthropoids it increases in length from the orang, who does not walk at all, to the gorilla, as follows: Orang, gibbon, chimpanzee, gorilla.

The orang has, indeed, a calcaneum shorter than any of the monkeys; he is also, as is well known, more aboreal in his habits than perhaps any other of the primates.

As to the races of man, it might have been foreseen that the primitive ones would have a calcaneum shorter than the higher ones; that is, in fact, what M. Volkov has shown, and establishing for an index the relation between the length of the calcaneum and that of the foot

[a] It is well known that the monkeys of the New World are more aboreal in their habits than any others.

taken through the second toe, he obtained the following results, to cite only the most characteristic:

Peruvians ♀	31.50
Polynesians ♀	32.30
Negros ♀	33.45
Europeans ♀	34.30

M. Volkov has also compared the posterior breadth of the calcaneum with the length of the foot and of the calcaneum itself. This breadth is proportionately less in climbers than in walkers, the Pitheci surpassing the Cebidæ in this respect, and man surpassing the anthropoids. When studied in the human species this ratio is found to be relatively greater in Europeans than in persons belonging to the primitive races. New-born Europeans resemble in this respect the lower races, even standing between the chimpanzee and the gorilla.

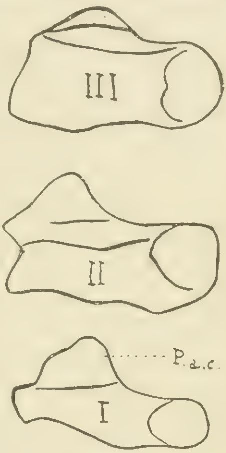


FIG. 6.—Calcaneum to show the development of the lesser process (inferior surface). I, Orang. II, Negro. III, European.

The lesser process of the calcaneum, the sustaining bracket of the walking foot, is broader in monkeys that walk than in those that are exclusively arboreal, among the Pitheci than among the Cebidæ. Among the anthropoids the orang has the smallest and narrowest process; he is also the most completely arboreal of the entire class; he never walks. However this may be, the lesser process of the calcaneum is always very long in monkeys. In man, perfectly adapted to walking erect on two feet, it is, on the contrary, very short, because of the formation of the arch, of which details will be given further on. In men of the inferior races it is much more developed than with us, and reaches almost simian dimensions. Because of the formation of the arch it is set farther up in man than in monkeys, and we see again that the Melanesian, for example, has in this respect an intermediate position between the gorilla and the European.

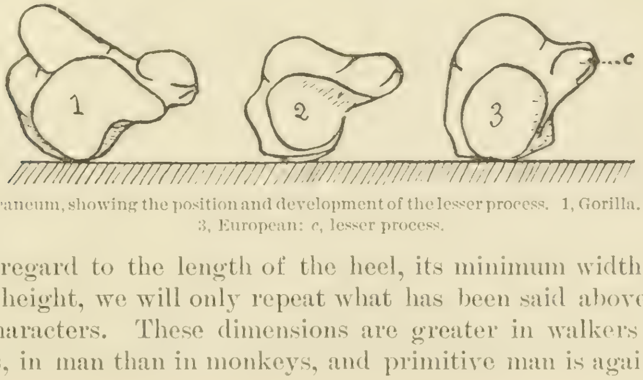


FIG. 7.—Calcaneum, showing the position and development of the lesser process. 1, Gorilla. 2, Negrito. 3, European: c, lesser process.

With regard to the length of the heel, its minimum width and its relative height, we will only repeat what has been said above for the other characters. These dimensions are greater in walkers than in climbers, in man than in monkeys, and primitive man is again found

to be a transition between civilized man and the anthropoid. Regarding the height there is an interesting fact to which I desire to call special attention, namely, that the height of the heel in Hylobates is very near that of man. This fact, connected with certain others, justifies us in giving special attention to the foot of the gibbon, an animal which in many respects approaches man, and it led Dubois, in his first memoir on Pithecanthropus, to compare the gibbon at once to that ancestor. The gibbon even surpasses in this respect the Veddahs, the negritos, and the negroes, as well as new-born children of our own race.

Another very important matter to which M. Volkov has directed his attention is the angle of inclination of the calcaneum. This angle of inclination, or rather the position of the calcaneum relative to the surface of the ground, has considerable influence on the formation of the arch, and consequently is contributory to all the variations just mentioned. In the lower apes, as well as in the anthropoids who have no well-marked arch, the calcaneum is placed, as it were, flat on the ground—that is to say, no angle of inclination exists. In the inferior races it is very small, and its minimum is reached in the Veddahs (♂ = 3° — ♀ = 10°) and the negroes (♂ = 6° — ♀ = 4°). In newborn Europeans it does not exceed 5°; its maximum is attained in adult Europeans in whom it is 14° for the male, 16° for the female. You will understand the great importance of this character; the inclination of the calcaneum is, I repeat, one of the principal elements of the plantar arch, the characteristic of the plantigrade, walking foot. Desiring, for clearness' sake, to treat, while speaking of the arch, of other characteristics of the calcaneum, I will examine only one more interesting feature of this bone, that of the articular facets for the astragalus found on the antero-internal surface. The older anatomists sometimes recognized two of these facets, sometimes one only. In his Traité d'anatomie M. Testut admits but one, which is sometimes, he says, divided into two by a transverse furrow.

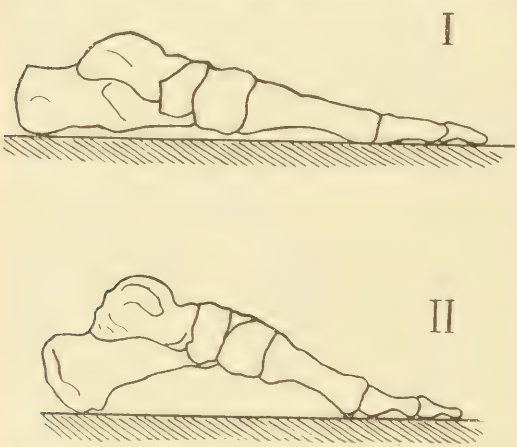


FIG. 8.—Skeleton of the foot (internal lateral surface). I, Negro. II, European (to show the angle of inclination of the calcaneum and the longitudinal arch).

M. Volkov has sought for the cause of this variation and has tried to determine its ethnic value. Following Camper, who had already remarked that the calcaneum of new-born children has always two

antero-internal facets on the astragalus, M. Volkov showed that monkeys possess the same peculiarity. In the chimpanzee and the gorilla, however, there is a distinct tendency for these facets to become united. The same tendency is observed in bears and all walking animals; finally in man, and especially in man of the so-called higher races, it is not rare to find the two facets completely blended, a feature less commonly found elsewhere. The separation of the antero-internal facets should be considered an atavistic character.

Scaphoid.—As M. Volkov has well remarked, the variability of this bone essentially depends upon that of the astragalus and first cuneiform which itself has a relation with the development, separation, and mobility of the first metatarsal and the first toe, which are, as is well known, characteristic of the tree-dwelling animals.

In the American monkeys, whose foot is especially adapted to an arboreal life, and who consequently have quite a mobile great toe, the inner edge of the scaphoid is very thick. It is less so in the monkeys of the Old World, who are even surpassed in this respect by the orang among the anthropoids. In the lower races of man the inner border of the scaphoid—that is to say, its tuberosity (whose real significance, we may say in passing, has been so well determined by M. Volkov)—is markedly better developed than in Europeans, a character evidently depending on the fact that with them the first toe, together with the head of the astragalus, is much less divergent.

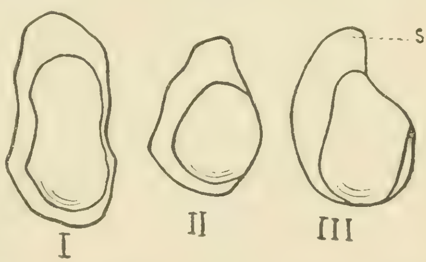


FIG. 9.—Scaphoid (posterior view). I, Gorilla. II, Negro. III, European. S, tubercle of the scaphoid.

M. Volkov has also directed his attention to the glenoid cavity by which the scaphoid articulates with the astragalus. He saw very clearly that this articular facet is, as one might expect, ovoid and much elongated from without, inward, in climbers, square, on the contrary, and slightly elongated in walkers. He established, for this articular surface, an index which increases from the climbers to the walkers, that is to say, among the monkeys from the Cebidæ to the Pitheci. Among anthropoids the orang appears to present, in this regard, an inexplicable anomaly; though he is the most arboreal of his class he possesses an index higher than the others; this exception is, however, easy to understand and even confirms, in my opinion, in a remarkable way, the general rule above enunciated. The orang is, indeed, the most arboreal of the anthropoids, and, on this account he shows a marked tendency toward an atrophy of the first toe (the first digit of the hand is likewise absent in a certain number of species of the primates, notably in the Colobus, one of the most characteristic arboreal Cebidæ). We are thus able to explain why the orang,

because of the very fact that he is arboreal to a supreme degree, possesses a reduced glenoid cavity; in man the primitive arrangement, that is to say, the one which is analogous to that of the arboreal animals is again found, as may be supposed, in negroes and the greater number of negritos, and the arrangement adapted to plantigrade locomotion belongs to the European.

It is strange to find that this peculiarity of the European foot, distinguishing it from that of the negro, recurs in certain rodents and marsupials of a primitive type. This must doubtless have piqued the curiosity of M. Volkov; he has, it seems to us, completely solved the enigma. The animals of primitive types have an extra bone, the external tibial, which in primates is fused with the scaphoid and forms its tuberosity. This explains the greater transverse dimensions which the scaphoid has in apes. In man, because of adaptation to walking, the scaphoid is reduced, and though it still possesses, coössified with it, the external tibial, it has assumed the reduced dimensions and the appearance of the autonomous scaphoid of primitive mammals.

I shall content myself with this too rapid and incomplete examination of these three most important elements of the human foot, and hasten on to a consideration of the foot as a whole, the real synthetic portion of M. Volkov's work.

Considering as a whole the foot, not merely of man alone but of all animals that walk upon their soles, such as the bear, for example, and one of a very remote class, the armadillo, we see that it is greatly differentiated from that of animals who use it but seldom, or not at all, for walking. Among the latter the skeleton of the tarsus is greatly lacking in solidity, the ligaments are relaxed, and the bones have rounded articular facets denoting movements of considerable amplitude. On the contrary, the tarsus of a plantigrade, such as man, is formed of angular bones with nearly flat articular surfaces, bound together by powerful ligaments, an arrangement indicating that its movements are very restricted.

It is the same with the toes. In arboreal monkeys they are very movable, the first is even opposable, while, in man, they remain bound together.

In the most arboreal monkeys, as is remarkably well shown in the orang, the metatarsals and the phalanges are bent, presenting a concave surface on the plantar aspect, an arrangement adapted for grasping branches; in man they are almost straight. Besides these characters, the foot of man has another important peculiarity which also assists in giving it the solidity required for plantigrade walking; that is, its arched condition.

The monkeys not adapted for walking have a flattened foot, and, as is well known, support themselves upon its outer border whenever they attempt to progress along the ground.

In man, on the contrary, the foot is arched and rests flat on the ground in standing and walking.

It is this arch which, acting as a sort of spring, enables the foot, as may easily be understood, to support a considerable weight;[a] it is, then, an improvement made with a view to walking, therefore it is not peculiar to man alone, and exists well developed in plantigrade animals who have considerable weight of body in comparison with the surface of the astragalus. The armadillo has a well-marked arch. M. Casse, in a very good paper on the ontogenetic development of the foot, compares the human foot to a tripod whose points of support would be the calcaneum and the heads of the first and fifth metatarsal bones, and whose summit, a broad curvilinear surface arched in two directions, would be occupied by the astragalus.

It is the astragalus, indeed, that transmits the weight of the body to the tripod. In order that the system may be in equilibrium it is evidently necessary that this astragalus should be situated in the bisector of the angle whose apex is formed by the posterior point of support C. This is precisely what occurs in man, whose foot is perfectly adapted to biped, plantigrade walking. M. Volkov noted that, among the primates, the development of this arch is in direct proportion to the more or less perfect adaptation to plantigrade walking.

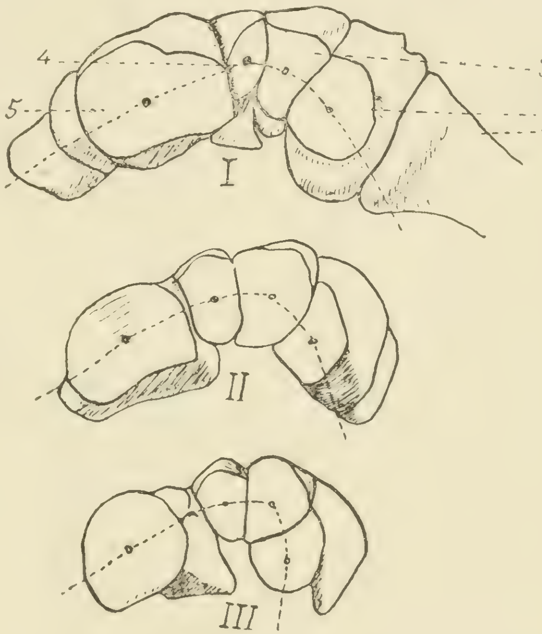


FIG. 10.—Transverse arch (the foot is disarticulated in front of the scaphoid and the calcaneum, and the anterior portion is here shown). I, Gorilla. II, Negro. III, European. 1, first digital ray; 2, first cuneiform; 3, second cuneiform; 4, third cuneiform; 5, cuboid. (The centers of figure of these bones are marked with dots, and a line drawn through these dots forms a curve which indicates the transverse arch.)

He studied separately the transverse arch and the longitudinal one. First he calculated the value of the transverse arch by measuring and comparing the actual breadth of the tarsus following its curvature from without inward, with the same breadth taken by projection; he

[a] In fact the dimensions of the human foot are augmented in every direction when it supports the weight of the body.

thus found that the weakest transverse arch is that of the orang, who never walks. In man, too, the minimum is represented, as before, by the men of the inferior races, the Australians and the negritos, the average by negroes and the maximum by Europeans (see fig. 10).

For the longitudinal arch, whose value was obtained by measuring the distance from the summit to the base of the arch, the foot being placed flat on the ground, M. Volkov arrived at the same results; at the bottom of the scale are the Veddahs, the negritos and the negroes, and at the top the Europeans; the foot of the European having the maximum of convexity.

M. Volkov has also studied the evolution of this arch, investigating how the flat foot of the tree dweller became such a structure as M. Casse has described, and the morphological changes of its constituent parts that have ensued because of the development of the convexity.

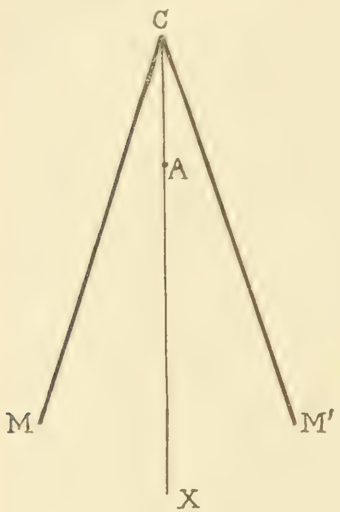


FIG. 11.—Diagram. C, point of posterior support. M, point of internal support. M′, point of external support. CX, anatomical axis. A, position of the astragalus.

One of the principal consequences of the formation of the arch has been the inclination of the heel to the ground, which we have already studied, and which, as would be supposed, varies directly as the degree of convexity,[a] this modification also occasioning a displacement of the insertion of the Achilles tendon.

The differences in the position and size of the lesser process of the calcaneum in man and anthropoids also vary according to the formation of the arch; its setting, for example, and the restriction of its dimensions. The monkey, for instance, whose foot is flattened and normally turned inward, has, indeed, a long and solid lesser process that sustains the astragalus; besides, by reason of the flattening of the

[a] It follows from the inclination of the calcaneum that the length of the heel in projection diminishes as the arch increases; this well-established fact explains the apparent contradiction between these results and the opinion generally expressed that the negroes have a longer heel than Europeans. As M. Volkov has shown, the men of the so-called inferior races have in reality, anatomically speaking, the calcaneum as a whole (and the heel itself) about equal to that of the Europeans when that bone is measured by itself and detached from its neighbors, but physiologically, since, as every one knows, we ought always in mechanics to measure the arm of the lever, it is longer in projection, which explains, as may be added parenthetically, the reason why the gastrocnemius muscle is longer and slenderer in the negro, shorter and thicker in the European. The well-known theory of M. Marey on this subject is completely confirmed by the figures of M. Volkov.

foot, this lesser process is set very low, being almost a continuation of the inferior surface of the calcaneum. The development of the arch in man had for its first effect the raising of this lesser process and then a reduction of its dimensions, the astragalus resting directly on the body of the calcaneum because of the approach of the latter to the anatomical axis[a] of the foot. This approach is, in fact, another character that varies with the development of the arch. In the anthropoids the heel is pushed strongly outward; in European man its axis coincides with the anatomical axis of the foot, and thus attains the position mentioned above and represented in figure 12.

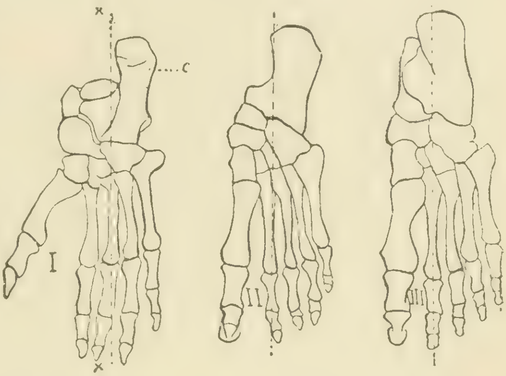


Fig. 12.—Skeleton of the foot (inferior surface). I, Gorilla. II, Negro. III, European. *c*, Calcaneum; *xx*, Anatomical axis (to show the deviation of the calcaneum).

Corresponding with the inverted position of the foot, the axis of the posterior surface of the calcaneum is in tree dwellers oblique from above downward and from without inward. As the arch becomes more completely formed, this axis becomes more and more perpendicular to the ground. It is not yet quite vertical in the Australian, but is so in the European. Men of the inferior races and new-born children have in this respect a position between the gorilla and the European adult, and in the arrangement of the different elements of the foot all is so well correlated that this deviation, more marked in anthropoids than in other apes, varies as does the divergence of the head of the astragalus, which is itself controlled by the freedom of movement of the first toe, another character of adaptation to arboreal life.

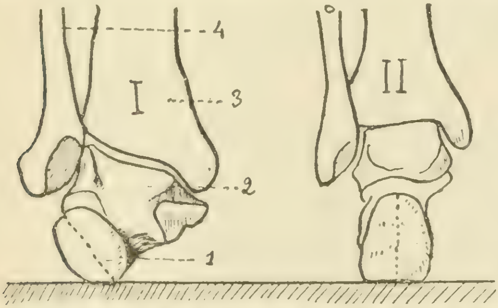


Fig. 13.—Skeleton of the foot and lower leg, showing the torsion of the heel. I, Gorilla. II, European. 1, Calcaneum; 2, Astragalus; 3, Tibia; 4, Fibula.

The adaptation of the arboreal foot to plantigrade walking and the development of the arch among the arboreals, also produced modifications in the astragalus both as to its position and to its form; we will

[a] The anatomical axis of the foot is the exact bisector of the angle C, corresponding nearly to the line which joins the middle of the posterior surface of the calcaneum with the space between the first and second toes.

cite first the already mentioned diminution, in the arboreal apes, of the angle which the body of the bone makes with its head, and we will also cite that peculiar torsion of the head of the astragalus, the major axis of which is in man directed from above downward and from without inward, while it tends to become horizontal in arboreals with feet having no arch, the apparent torsion in man being manifestly due to the approximation of the great toe and the upward thrusting of the lesser process of the calcaneum.

Another very important modification is one to which M. Testut had the merit of first calling attention; that is, the displacement of the axis of the trochlear surface of the astragalus. Since the arboreal apes have an inturned foot they have an astragalus whose trochlear axis tends to occupy a position farther and farther from the anatomical axis. In man, because the foot has changed to a position at right angles to the limb, the axis of the trochlear surface tends to approach the anatomical axis nearer and nearer; that is to say, to coincide with the bisector of the angle C (fig. 11). By this character, too, the inferior human races present, as always, interesting features of resemblance to the arboreal ancestors. Since the trochlea of the astragalus fits, as is well known, into the tibial mortise, when its axis is displaced it must necessarily involve modifications in the position and form of the tibia which has for this reason suffered a certain torsion from without inward, whose effects are shown even as far up as the femur (see fig. 14).

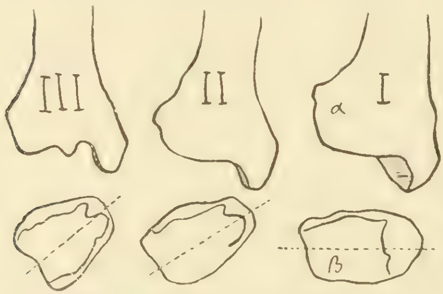


FIG. 14.—Lower end of the tibia (a, rear view; B, view from below). I, Gorilla. II, Negro. III, European.

To conclude, the position of the foot is modified by the development of the arch—in climbers the sole is turned inward, in man it is flat on the ground. It follows that the inferior tibial mortise must look inward in the first, while in the two last it is horizontal, and here again the negro stands between the European and the gorilla.

I do not wish to abuse your patience longer, but, in terminating this too long exposition, in which the great abundance of details, on which I have been unable to expatiate, has, perhaps, been tiresome and difficult to follow, I think it will be useful to recapitulate and to sketch, in conclusion, what I understand to have been the course of development of the human foot.

The foot of monkeys, as you have seen, shows a number of characters, which may be summarized as follows:

It is turned inward, it is flat, its articulations are loose and mobile, its first toe is mobile and separated. From these general characters

it follows that the upper part of its calcaneum is turned outward and the trochlear surface of its astragalus is likewise oblique and looks outward; it also results from this that its calcaneum is flattened and provided with a long lesser process set near the ground; these occasion further modifications in the tibia, as we have just seen, and even in the femur.

The foot of man, on the contrary, is placed at right angles to the axis of the limb—it is arched, its articulations are almost immovable, its first toe is closely attached to the others, all these arrangements tending to give the organ the solidity and flexibility required for biped locomotion. To these general features are added others of a special character, the principal of which are: The shifting of the calcaneum and the trochlear surface of the astragalus into the anatomical axis of the foot, and the torsion of the tibia above mentioned; the first feature relates to the arboreal adaptation, the second is the result of a gradual improvement with reference to biped and plantigrade locomotion. The stages intermediate to these two conditions, which we find so clearly marked in the foot of the inferior races of men, prove incontestably that our foot is derived from an arboreal foot analogous to that of the monkeys of to-day, our remote cousins, which has left its traces in our species.

Our convictions in this regard are confirmed when we see that the foot of new-born infants of our race reproduces the features of that of men of the inferior races, often assimilating even nearer than that to the arboreal, simian foot, especially to that of the gorilla, which appears to be decidedly the most nearly related to the human foot. The course of ontogeny here again reproduces that of phylogeny; comparative anatomy and embryology once more agree.

In this investigation one chapter is yet wanting or, rather, may seem to you insufficiently developed—that is to say, one in which there would be investigated the feet of men belonging to the prehistoric races. M. Volkov has not yet been able to undertake this investigation, but it is probable that the results he may obtain by it will merely confirm those already secured; we have a right to suppose this, especially since M. Testut has found in the man of Chancelade a separated great toe like that of the lower human races of to-day and almost as marked as among the anthropoids.

The arguments derived from every line of research would then be in substantial agreement.

Toward what does the foot of man at the present day tend? Does its arch tend to increase and its constituent parts to more firmly coalesce? The question is a difficult one; it seems, however, that in our race, particularly among the females of our own country, the foot has attained the maximum of perfection for the functions required of it.

THE NAME MAMMAL AND THE IDEA EXPRESSED.[a]

By Theodore Gill.

One of the most natural of the polymorphic groups of the animal kingdom is the class of mammals, but yet it was less than a century and a half ago that it was recognized. It was, in fact, the fruit of scientific research and logic and not of popular recognition. Popular and scientific classifications of the animal kingdom, far from being parallel or the one merely an extension of the other, have been often directly opposed. From the earliest times, the Aryan and Semitic peoples at least considered animals in aggregates with reference to the functions exercised rather than with reference to agreement in structural details; in the language of the naturalist, they segregated them by physiological characters rather than morphological ones. There was, too, a curious association with what were called the "elements"—earth, water, and air. (Fire was without its animals, unless the fabled salamander be regarded as one.) This association was in olden times generally accepted. It appears in the Jewish tale of creation given in Genesis (i, 1, 2, 7, 9, 20, 24); it appears in the Roman mythology perpetuated in Ovid's verse (Metam., I, lines 5–7, 21, 22, 72–75).

In popular natural history, the hairy quadrupeds were associated with the scaly and naked ones as quadrupeds, the sea-dwelling cetaceans were combined with the scaly fishes in another class, and the volant bats were sometimes grouped with quadrupeds on account of their obvious likeness to mice, except for the wings, and sometimes with birds because they could fly. So all continued to be grouped through the ages. Aristotle did no better, or at any rate little better, than those preceding him and those following him for many centuries. The assertion of Owen that Aristotle fully recognized the class of mammals under the name Zootoca is without proper foundation. Long ago, in the American Naturalist (VII, 458), I showed that different passages in Aristotle's book negatived such a statement and that the word zootoka was never used as a substantive.

[a] Much of the present article was published in September, 1902, in the Popular Science Monthly under the caption "The story of a name—Mammals."

At last a very bright English naturalist, the greatest naturalist of the seventeenth century, John Ray, was suggestive in this, as in many other cases. Ray, in his Synopsis Methodica Animalium Quadrupedum et Serpentini Generis (1693, p. 53), gave an "Animalium tabula generalis" in which he bracketed the terrestrial or quadruped mammals with the aquatic as vivipara, and contrasted them with the ovipara or aves. The vivipara are exactly coextensive with what were later called mammalia, but the word vivipara was used as an adjective and not as a noun. This was a most happy suggestion, but it was long before it was acted on or before anyone advanced as far in the appreciation of the facts involved.

Linnæus, the Swedish naturalist, published the first edition of his Systema Naturæ in 1735, and in that and every succeeding edition up to the tenth adopted the idea current for so many generations, so far at least as the union of cetaceans with fishes was concerned. But in 1758 he at last caught on to the idea of Ray and for the first time separated the cetaceans from the fishes and combined them with the hairy quadrupeds in a special class. There was no name for that class; for though Ray had suggested the grouping of the two together, he did not propose a collective name. A new name, therefore, had to be given, and that was "mammalia." Some curious mistakes have been made respecting this name.

In the great Century Dictionary, a deservedly esteemed work, and which may generally be implicitly trusted, the etymology of mammalia is given as "NL. (sc. *animalia*), neut. pl. of LL. *mammalis* (neut. sing. as noun, *mammale*), of the breast: see *mammal*," and, under mammal, we have "*a.* and *n.* [=OF. *mammal*=Sp. *mamal*=Pg. *mamal*, *mammal*=It. *mammale*, n.; < NL. *mammale*, a mammal, neut. of LL. *mammalis*, of the breast, < L. *mamma*, the breast]."

All this is misleading, if not absolutely erroneous. The name "mammalia," as just indicated, was first coined and used by Linnæus, and was formed directly from the Latin; it had nothing whatever to do with French, Spanish, Portuguese, or Italian words. The concept of which the Linnæan word is the expression is as remote from a popular notion as could well be, and even the necessity for the word (or an analogous one) can be appreciated really only by the educated or, pro tanto, the scientifically educated. Buffon and Pennant, for example, could not realize the reason for its use.

It is noteworthy that, in the Century Dictionary, even the very word that might have given the clew to the formation of "mammal" is cited, and yet the excellent professional etymologist who worked on it was not guided into the right path. With the hint given to him, he failed to see the point. Evidently, then, the etymology is not as obvious as it might seem to be.

Often, indeed, in looking over etymologies, one must be impressed with the insufficiency of philological learning alone for the solution of knotty questions. A living knowledge of the objects named, as well as of their history, is often requisite for a full understanding of the significance or aptness of the names.

It was one of the happiest inspirations of Linnæus to segregate all the mammiferous animals—the hairy quadrupeds, the bats, the sirenians, and the cetaceans—in a single class. No one before had appreciated the closeness of the relations of the several types, and there was no name for the new class (or concept) as there was for all his other classes. A name, therefore, had to be devised. It was another happy inspiration that led Linnæus to name the class "mammalia." Those who are familiar with the works and ratiocination, and especially the nomenclature, of the great Swede may divine his thoughts and share with him in the execution of his ideas, although he did not give etymologies. For those "animalia" which are animals par excellence he would coin a name which would recall that fact. (Animal, be it remembered, is often used in popular converse in the sense of mammal.)

The name in question was evidently made in analogy with animalia. In animalia the principal component was *anima*, the vital principle, or animal life. (Old Nonius Marcellus well defined and contrasted the word—"animus est quo sapimus, anima qua vivimus.") The singular of the word was animal. In mammalia the essential component is *mamma*, breast; the singular should be mammal. The terminal element (-al) was coincident with rather than derived directly from the Latin suffix (-alis) which expressed the idea of resemblance or relationship; anyway, it was used in substantive form, and the idea of possession or inclusion was involved, as in the case of animal, capital, feminal, tribunal—all well-known Latin words. In fine, a mammal is a being especially marked by or notable for having mammæ.

The truth embodied in the word was almost immediately appreciated by most naturalists at least, and the class of mammals has been adopted ever since the Linnæan period by zoologists. Naturally the new Latin name was to some extent replaced by names in the vernacular tongues of most nations.

In the accommodating English alone the Latin word was adopted with only a change in its ending, and thus the class name "mammals" was introduced, and the singular form—"mammal"—followed as a matter of course, and by chance (or rather the genius of language) exactly coincided in form with the singular of the Latin word.

Not only had the name nothing to do with the alleged derivative Latin words—it was not admitted at all into the vernacular speech of France, Spain, Portugal, or Italy. The naturalists and lexicographers

of those countries failed even to appreciate its etymological aptness and beauty. First, the French had to introduce a new word to correspond—mammifères, or the breast-bearers. The other Latin races followed; the Spanish and the Portuguese with mamiferos, and the Italians with mammiferi. None of the words quoted in the Century Dictionary are even given as nouns in the ordinary dictionaries of those languages—not even in the great dictionary of Littré. Littré, however, has the words mammalogie, mammalogique, and mammalogiste.

Of course the Germans coined a word from their vernacular—Säugethiere, or suckling animals. The cognate nations imitated—the Dutch with Zoogdieren, the Swedish with Däggdjuren, and the Danes and Norwegians with Pattedyrene.

But, although the English proved ultimately to be so "accommodating," the full acceptance of a name in the vernacular speech was long delayed. Very early the equivalent words had been cordially welcomed in the continental languages, but the users of English were chary in their admission of foreigners.

Even the English word in plural form—"mammals"—was grudgingly admitted; the Latin form—"mammalia"—was long preferred. The chief translators of the Règne Animal rendered mammifères by "mammalia;" Blyth alone substituted "mammalians" in its place. Owen, in his History of British Fossil Mammals, employed "mammalia" in the text more frequently than "mammals," and yet he used the English form more than any of his contemporaries. Popular as well as scientific writers avoided the English word as one alien to the genius of the language. Some preferred the word "mammifers" when they would use an anglicized term.

By reason of the general ignorance of the etymology of the word "mammalia," and the dislike of it on account of the misapprehension that it was an imperfect or clipped word, one of the French naturalists devised a substitute—"mammifères"—and this early took root and has been universally adopted by French writers. It was to some extent adopted by English writers of the first half of the last century under the form "mammifers." Robert Chambers, in his anonymous Vestiges of Creation, frequently used it, and Hugh Miller, in his antidotes to the heresy of the Vestiges, sometimes did. Miller, in his Old Red Sandstone (1841), also accepted the singular form in his statement (Chapter IV) that "the mammifer takes precedence of the bird, the bird of the reptile, the reptile of the fish." The use of the word, nevertheless, was never general. The derivative adjective, however, was much more frequently adopted for a time.

Lyell, in his Principles of Geology, almost invariably used the word "mammalia," but accepted the adjective "mammiferous" instead of "mammalian" and even of "mammaliferous." (He admitted

"mammifers" in his Glossary, but did not otherwise use it.) This, naturally, was an example which others followed. It was not until the first half of the century had been past for some time that the English word came generally into use.

In the most trivial fiction the Latin "mammalia" was used instead of the English "mammals." An example of this may be given, inasmuch as it will also serve to show how, by accident or design, a possible solecism was avoided. Edgar Allan Poe, the precursor of Conan Doyle as author of "detective stories," in 1841 published a thrilling story of The Murders in the Rue Morgue. The supposititious narrator is an American resident in Paris, and has a French friend (M. Dupin) notable for the acuteness of his analytical and detective faculty. An unaccountable murder of two women was committed, and the police as well as professional detectives of Paris had been unable to solve the mystery. The amateur, M. Dupin, investigated, satisfied himself, and explains to his friend his solution. "Read, now," says Dupin, "this passage from Cuvier." The American summarizes in his own language: "It was a minute anatomical and generally descriptive account of the large fulvous orang-outang of the East Indian Islands. The gigantic stature, the prodigious strength and activity, the wild ferocity, and the imitative propensities of these mammalia are sufficiently well known to all. I understood the full horrors of the murder at once."

Now, as it was an American that gave the account, it was perfectly right, at the time in question, to use "mammalia." But if Poe had put that word in the mouth of Dupin, or as emanating from the pen of Cuvier, he would have done violence to French usage. The scientific men of France as well as popular writers always used their vernacular "mammifères;" and if the American would have translated to represent the French style he should have used "mammifers" or "mammals." To have rendered it by "mammalia" (as many would) would have been paraphrastic, but not translation of the spirit of the French.

The first writer to use the English word "mammals," at least to any extent, was Dr. John Mason Good. In his Pantologia (Volume VIII, 1813) he formally introduced the English name, under "Mammalia," in the following words:

> In English we have no direct synonym for this term; quadruped or four-footed, which has usually been employed for this purpose, is truly absurd, since one of the orders have [sic!] no feet whatever, and another offers one or two genera that can not with propriety be said to have more than two feet. We have hence thought ourselves justified in vernacularizing the Latin term and translating "mammalia," mammals, or breasted animals.

In Volume XII, in the articles "Quadruped" and "Zoology," Good also used the word "mammals" apropos of the classification of Lin-

næus, and in other places,[a] and also in the article on "Quadruped," the adjective "mammalian."

The same Good, in The Book of Nature (1826) and in the second lecture of the second series, "On zoological systems," again specifically introduces it. Quadrupeds is not appropriate, "and hence it has been correctly and elegantly exchanged by Linnæus for that of 'mammalia,'" and he concludes, "As we have no fair synonym for it in our own tongne, I shall beg leave now, as I have on various other occasions, to render 'mammals.'" He repeatedly used the English form elsewhere in The Book. I have been unable to find any use of the word in its singular number, however.

The singular form, "mammal," has been indicated as rare or unusual. One might look through many volumes on mammals, as well as on general natural history, and not find it. As a matter of fact, however, it may be frequently used. Let us go, for example, into a laboratory when they are assorting a miscellaneous lot of bones gathered from some fossil ossuary. Such expressions may be heard as "that *seems to be* a mammal bone;" "that *is* a mammal bone;" "that is a *mammal* bone;" "*that* is a mammal bone"—or the substantive "mammal" alone may be used. Further, a whale may be alluded to as a gigantic mammal or a mammal giant.

The earliest English author to use the singular form, so far as known, was Richard Owen. In his History of British Fossil Mammals and Birds (1846), for example, he alluded to a mastodon as "this rare British fossil mammal" (p. xxii), and asserted that he knew "of no other extinct genus of mammal which was so cosmopolitan as the mastodon" (p. xlii); he said that "the myrmecobius is an insectivorous mammal, and also marsupial" (p. 40), and he claimed, conditionally, that "the Meles taxus is the oldest known species of mammal now living on the face of the earth" (p. 111). Robert Chambers, in editions of the famous Vestiges of Creation, published afterwards, also used the singular number in several cases (e. g., Harper ed., pp. 110, 280), although in earlier editions (1844 et seq.) he used "mammifer" (e. g., p. 103). So, likewise, did Hugh Miller in his later works. In an extension of the statement respecting the succession of the vertebrate classes already referred to, mammal is used instead of mammifer. In the chapter on "final causes" in The Footprints of the Creator (1847) it is claimed that an increase in size of the brain in comparison with the spinal cord is correlative with the succession of the animals; after the brains of the fish, reptile, and bird, "next in succession came the brain that averages as four to one—it is that of the mammal." Elsewhere (Boston ed., p. 238) the singular is also used and the plural "mammals" often.

[a]The volumes of the Pantologia are not paged, the alphabetical arrangement having been thought to supersede pagination.

But some English authors who were willing to use a vernacular substitute for mammalia would have neither mammals nor mammifers.

The Rev. William Kirby, in 1835, in the once famous Bridgewater treatise On the Power, Wisdom, and Goodness of God, as manifested in the Creation of Animals and in the History, Habits, and Instincts, declined to accept either, but invariably used, as the English equivalent of mammalia, "mammalians." Chapter XXIV is entitled "Functions and instincts. Mammalians;" in this, it is explained, "the whole body, constituting the class, though sometimes varying in the manner, are all distinguished by giving suck to their young, on which account they were denominated by the Swedish naturalist 'mammalians'" (II, p. 476). In a footnote to this statement, Kirby adds, "Cuvier calls them 'mammifers,' but there seems no reason for altering the original term."

We may cordially indorse the sentiment of Kirby, and, doing so, refuse to follow him in action and to adopt his modification of "the original term," and revert to the genuine original—mammals, or, in the singular, mammal.

No instance of the use of the singular—mammalian—has been found in Kirby's work or in any of his successors', nor does the singular form "mammal" occur in the Pantologia. There is, indeed, one instance of its use in the Vestiges of Creation (Harper ed., p. 284); but as it was followed by a plural verb, it was inadvertently used.

The science which treats of mammals had to be named. Mammalogy was naturally thought of, but many objected to it. The French, who would not tolerate mammal or mammaux, although they had no objection to the analogous animal and animaux, on the whole took kindly to "mammalogie" or "mammologie." Substitutes, it is true, were offered; Desmarest proposed "mastologie" and De Blainville "mastozoologie," and the latter was admitted by Littré to his great dictionary, but they did not secure a permanent foothold, and "mammalogie" is the term now generally used.

The objection to "mammalogy" was and is that it is a hybrid and also a badly compounded and clipped word. It is formed of the Latin mamma (a breast or teat) and the Greek suffix, -λόγία; the apparent meaning is a discourse on breasts rather than breast-bearing animals. Greek nouns also generally have the vowel "o" rather than "a" before the second component. There is no simple word λόγία in Greek meaning discourse, and the suffix in question is connected with the word λόγος or, rather, the verb λέγω. The only Greek word λόγία (occurring in the first Epistle to the Corinthians, xvi, 1, 2) means "a collection for the poor," and therefore λόγία is misleading and has misled several to my knowledge. The Greek words "dikologia," "etymologia," "philologia," and "theologia," of course are

good precedents for the English words ending in "-ology" and consequently we may use, as a suffix, -λόγία (but not simply λόγία) in explanation of the etymology.

In view of all its faults, suggestions were made to correct the word to "mammology" if not "mammalology." Others would compound a name of two Greek constituents (θήρ, a wild beast, and λόγος). Therology was the result. Dr. John D. Godman, in his American Natural History (1824), entitled the first (and only published) part "Mastology," thus borrowing a word first used by Desmarest. The writer of the long article on "Mammalia" for the Edinburgh Encyclopædia (1819) coined the word "mazology" (μαζος, a breast, and λόγος, discourse). None of these words has found general admission into the language. Notwithstanding the philological objections, mammalogy of late years has been generally accepted, and general consensus establishes its right of being.

On a previous page it has been affirmed that "animal is often used in popular converse in the sense of mammal." One of the many cases that might be cited is furnished by a justly esteemed author in a recent number (March, 1904) of The Century Magazine. John Burroughs, in an article "On humanizing the animals" (p. 779), has contrasted the word with birds. He says: "There seems to be among the birds something that is like what is called romantic love. The choice of mate seems always to rest with the female, while among the *animals* the female shows no preference at all." As the present article is intended only to show the use of words no comments are necessary, save to add that Mr. Burroughs excepts from his generalization "certain birds of India and Australia."

The word animal is made to do duty, in the same article, both as the equivalent of the Latin "animalia" and "mammalia." In the larger sense it is used (p. 773) apropos of "the wariness of wild creatures" and "why flocks of birds, droves of beasts, and schools of fish act with a common impulse." To contrast with other classes, "beasts" is then the word used in place of "mammals." How much better it would be to use "mammals" in every case where such are meant. Ambiguity would be avoided; precision insured. There is need of the word, and English-speaking peoples are as well entitled to its use as all the other European nations are to employ analogous words.

EXPERIMENTAL STUDIES ON THE MENTAL LIFE OF ANIMALS.[a]

By N. Vaschide and P. Rousseau.

Among the problems attacked by modern experimental psychology, that of the mental life of animals has a prominent place, all the more important because upon its solution depends, in a great degree, the exactitude of our knowledge concerning the evolution of mental activity in the scale of life.

We know very little about the minds or mental life of animals, and the scanty knowledge we possess concerning their intelligence is largely mingled with legend. Everyone who owns a dog thinks himself a psychologist and that he has made exact observations on animal mentality when he brings out a few simple phenomena that he calls "experiments." These are the defenders of the old maxim of the deep significance of simple observations.

In another field we note the remarks of professional people, meeting everywhere with citations, after the manner of the illustrated journals, of thousands of methods of capturing animals, methods whose success is believed to indicate the possession by animals of a well-developed imagination. It has even been supposed that we can follow the complex processes of creative animal imagination!

In this article we will give an account of the experimental investigations of the American psychologist, Mr. Edward L. Thorndike.

I.

Animal psychology has, up to this time, remained in a somewhat rudimentary state; those authors who have occupied themselves with studies of that nature have a tendency to explain the mental life of animals by associative processes. That life being essentially made up of reactions to impressions arising empirically, produced either by the influence of hereditary instincts or the personal experience of each animal, it seems unnecessary to appeal to phenomena of abstraction and inference and to concepts in order to explain it. Our author considers that this general tendency is good. It is not, however, so regarded by all psychologists, and even those who hold it are still

[a] Translated and condensed from the Revue Scientifique (Paris), June 13 and September 12, 1903.

inclined to views that are too synthetical. We must study the formation of associations in a more fragmentary and analytical manner. We too easily content ourselves with words and vague formulas; it is common sense, not the scientific spirit, the spirit of criticism and analysis, that still makes laws in this very special domain of psychology. I call my cat to give her a saucer of milk to drink. What is the exact series of images developed in her mind from the moment when the sound strikes her ear to that when she decides to obey? To say that the animal has present in her intelligence a more or less complex process of association is to be contented with very little. We limit ourselves to saying that she does not reason—which appears quite evident—and yet that her acts accord with elements other than purely instinctive phenomena. To fix the meaning of the expression "process of association" as applied to animals, to give it a positive signification, to ascertain what processes of this kind can be formed in their minds, and of what degree of complexity and delicacy, what would be the duration of such processes and the conditions of their formation—such is the problem, precise and clearly limited, that Mr. Thorndike[a] set himself to solve. He has given us a clear statement of his method and a very complete illustration of it. Two qualities are found united in his work: On the one hand, the faculty of making us grasp the detail of his facts; on the other, that of bringing out clearly the scope and interest that this question presents for general and comparative psychology.

Strictly from the point of view of method the older or even contemporary psychology presents a number of grave defects. It tends toward a perpetual eulogy of animals, as with Romanes, for instance. Psychologists are too easily moved to astonishment and admiration. This disposition, which tends toward puerility, ends by falsifying the method itself, by leading to the choice of those facts only that excite admiration or enthusiasm. A more objective attitude is necessary.

In the first place, most of the books do not give us a psychology, but rather an eulogy of animals. They have all been about animal intelligence, never about animal stupidity. Though a writer derides the notion that animals have reason, he hastens to add that they have marvelous capacity of forming associations; that human beings only rarely reason anything out; that their trains of ideas are ruled mostly by association, as if, in this respect, animals were on a par with them. The history of books on animals' minds thus furnishes an illustration of the well-nigh universal tendency in human nature to find the marvelous wherever it can. We wonder that the stars are so big and so far apart, that the microbes are so small and so thick together, and for much the same reason wonder at the things animals do. Now, imagine an astronomer tremendously eager to prove the stars as big as possible, or a bacteriologist whose great scientific desire is to demonstrate the microbes to be very, very little. Yet there has been a similar eagerness on the part of many

[a] Edward L. Thorndike: Animal intelligence; an experimental study of the associative processes in animals. Series of monograph supplements to Psychological Review. Vol. II, No. 4, June, 1898.

recent writers on animal psychology to praise the abilities of animals. This can not but lead to partiality in deductions from facts and more especially in the choice of facts for investigation. How can scientists who write like lawyers, defending animals against the charge of having no power of rationality, be at the same time impartial judges on the bench?[a]

Finally, even the writers who might have won valuable results have contented themselves with arguing against theories of the eulogists. They have not yet made investigations of their own.

Further, animal psychology has been hitherto too much derived from anecdotes; authors cite only those facts that are exceptional, extraordinary, or considered as such, instead of which the normal and simplest cases should always be reported. Anecdotes also have the disadvantage of being rarely given at first hand. Finally, by their very definition they are unverifiable.

II.

The method adopted should be an exclusively experimental one, and that alone is what Mr. Thorndike has used. It is essentially a method of observation and experiment, submitted, as in all such cases, to a certain number of constant precautions. It was necessary here more than elsewhere to avoid making generalizations from the individual to the species on observations of only a single case, to regulate in a precise manner the conditions of each experiment as far as possible, and to use in these experiments only animals whose previous history was known, all of which precautions seem to have been ignored by preceding psychologists. This objective attitude once adopted, there were still some details to be arranged. It was necessary to formulate a plan—to establish a certain number of constant points which, in the whole series of experiments, would serve as guides for the observer. Mr. Thorndike reduces these points to three, formulated as the three following questions, which constitute the logical structure of the method:

1. What is it the animals under observation do?
2. How do they do it?
3. What do they feel while they thus act?[b]

The theoretical aspect being thus settled, it became necessary to determine the material and psychological conditions of the experiments. The principle kept in view was to select an experiment or series of experiments which should be at once simple and at the same time significant. From a psychological point of view it was necessary to manage so as to have only a restricted number of known psychological elements. Our author adopted the following ingenious stratagem: Using for his experiments cats, dogs, and chickens, he deprived

[a] Thorndike, pp. 3 and 4.

[b] Thorndike, p. 5.

of food for some time—twenty-four hours, for example—the animal which was to be the subject of the experiment; then he shut it in a cage having a grating front; near by, on the outside, food for the animal was placed. The door of the cage, set into the grating, was moved by a mechanism which the animal had to operate in order to get out; once free, he could satisfy his hunger. In general, the animal was put into the box through a hole either in the back or the top. This hole was then covered over by a board. The door in the various cages could be opened either by a latch, a button, by pulling a cord, or by stepping on a platform. Sometimes it was fastened by two or three means, which had to be operated by the animal before its release was effected. When our author used chickens he sometimes modified his procedure. In place of having to open a door, the subject was placed in a small inclosure and had to surmount successively a certain number of obstacles—walk up steps, for example—to find its food and companions. The basis of the principle remains the same; the animal has, in all cases, to form an association between the representation of the interior of the box presented by his senses and the series of movements which release it, hunger being the excitant.

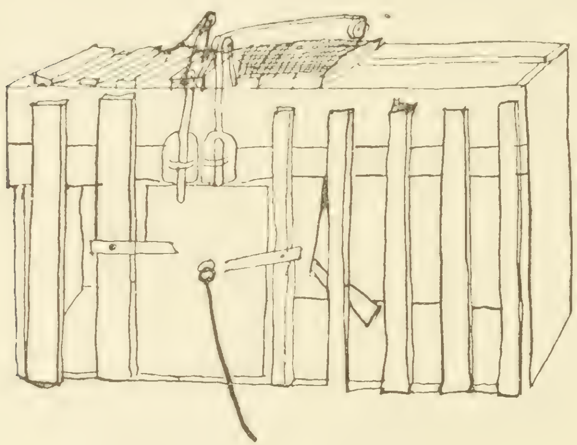
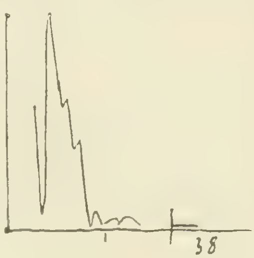


FIG. 1.—General model of a box (Box K).

After the animal was shut up, its conduct was carefully observed. A double precaution was taken; first, to note if the subject of the experiment had or had not previously been subjected to the same or some similar experience; finally, which was quite easy with the arrangements adopted, to be quite sure that the animal was free from any influence of the observer; the "personal equation" connected with the latter being entirely eliminated. It was only manifest in the theoretical interpretation of the experiment. The animal's behavior was quite independent of any factors save its own hunger, the mechanism of the box it was in, the food outside, and such general matters as fatigue, indisposition, etc. Animals in doubtful health were not considered. In order to be sure as to the psychological motive involved, the author, in the case of dogs and cats, did not experiment with them until they were in a uniform state of absolute hunger. As a general rule, if the animal placed in the cage did not, after a certain time,

succeed in getting out, he was taken out, but not fed; shortly after the experiment was recommenced with him. If, after a sufficient number of trials he failed to get out, the case was considered a failure. Enough animals were successively tried in each box to make it sure that the results were not due to individual peculiarities. As chickens could not be subjected to extreme hunger without danger of death, the author used for them, as a psychological motive, the dislike of loneliness, which is very great among those animals.

The associations which it is thus attempted to form are entirely new to the animal; they are such as could hardly have been experienced by it in the course of its past life, still they are not too remote from the ordinary course of its mental activities. They express the connection of a certain act with a certain situation and the will that results from that relation. The movements required by the act are those habitual to the animal; we may therefore consider the experiments as near as possible to the acts normal to the animal's life. As the acts required are near enough like those reported by the anecdotic school, we may compare the results obtained by this method with those furnished by that school. The results are schematically expressed in a graphic manner by curves which permit a rapid comparison of many experiments or the following of them through their different stages. The arrangement of the method seems excellent: let us see now its results.



No 3 in A.

FIG. 2.—Thorndike, p. 18, fig. 2.

III.

A. *Experiments concerning association.*—These have been directed with reference to four principal inquiries: (1) How and under what conditions is association formed? (2) What are the psychological elements that compose it? (3) What is the nature of the associations formed? (4) What is their complexity, number, and duration?

First. *How and under what conditions is association formed?*—The experiments were made on 13 cats, whose ages varied from 3 to 19 months; on 3 dogs, of which one (No. 1) was 8 months old and the two others were adults, all three being of about the same height; about 10 chickens were also used.

The behavior of the cats, with the exception of two, the oldest (No. 13) and one of a naturally apathetic disposition (No. 11), was always the same. All gave at first violent signs of discomfort when put into the box, clawing and biting at the bars, thrusting the paws out at any opening. These violent acts lasted eight to ten minutes. All manifested at first a desire to escape; they did not pay very much attention to the food placed outside. By dint of scratching and biting they all at last succeeded in touching accidentally the

button or the string that opened the door; a connection thus tended to be established between the act of opening the door and that of going out; gradually all the movements that did not result in the delivery of the subject, not being finally accompanied by the feeling of pleasure resulting from that deliverance, would be stamped out. The impulse[a] that terminates in setting the subject at liberty would be stamped in by the resulting pleasure; this particular quality would cause it to predominate in the consciousness of the animal in a more or less exclusive manner; after many successful trials the cat would, when put into the box, immediately claw the button or the bolt that closed its prison. A progressive modification of its entire attitude was produced. A cat, placed successively in two boxes, manifested in the second one less desire to attempt escape through the bars; it almost ceased to mew; if it got out of the first box by scratching, it showed a marked tendency to scratch when placed in the second; there was shown then, to a certain degree, an adaptation of movements to effect a desired end.

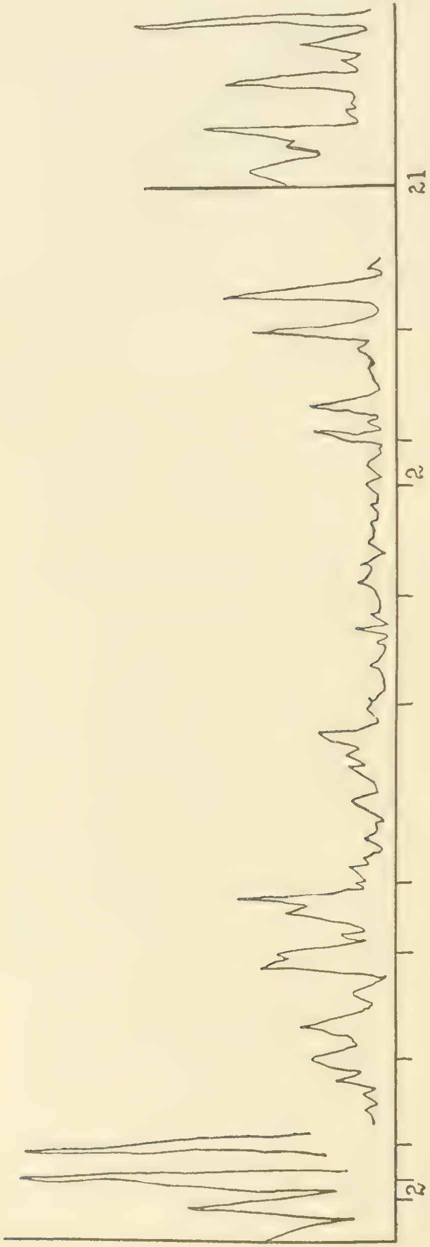


FIG. 3.—Thorndike, p. 25, fig. 9.

Here are some figures: Cat No. 12, from 4 to 6 months old, placed in a box closed by a bolt, first took 160 seconds to get out; finally it did this in a minimum of 5 seconds. The intermediate figures show an almost regular decrease: 160, 130, 90, 60, 15, 28, 20, 30, 22, 11, 15, 20, 12, 14, 10, 8, 8, 5, 10, 8, 6, 6, 7 seconds. An inter-

[a] The word "impulse," as used by Mr. Thorndike, means the consciousness accompanying a muscular innervation; it is the direct feeling of the doing as dis-

val of 24 hours separated the last two attempts. When the method of closing the door was simple—if, for example, it was released by pulling upon a cord situated outside the bars or by turning a button—100 per cent of the cats succeeded. In cages having a more complicated method of closing, irregularity began. Cat No. 2, from 5 to 7 months old, did not succeed in getting out of the box marked "K," which required three acts to open it. The rapidity with which an association is formed varies considerably. It may be considered as easily formed when it passes from a maximum of 300 seconds to a minimum of 6 or 8 seconds in five or six attempts; it is formed with difficulty when the same result is attained only after 30 attempts. Observation of the conduct of animals shows that the rapidity depends on the hereditary aptitudes of the subject, on its past experience, on the attention which it gives to the act. A cat may scratch without attending to any object in particular, but if it accidentally shoves back the bolt its attention will be fixed upon that movement and that particular object. Finally, account must be taken of the greater or less vigor and the more or less abundant movements of the animal. Attention is often correlated with a certain lack of vigor; the association in this case is more easily formed; a less exaggerated display of activity, a greater calm, allow the animal to be more conscious of what is necessary to do.

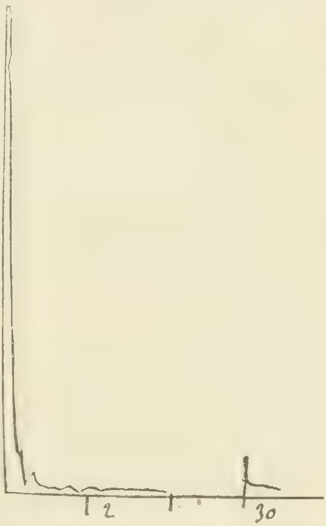


Fig. 4.—Cat No. 3 in box A. Thorndike, p. 22, Formation of association.

Among the 50 graphic tracings that our author presents we notice the two curves shown in figs. 2 and 3 relating to cat No. 3, shut up first in box A, closing with a bolt; then in box K, in which three modes of closing were employed. The number of trials is carried on the line of the abscissas, as well as the intervals that occurred between each attempt; the duration of each attempt is carried on the ordinates, each millimeter representing 10 seconds. The extreme difficulty which the animal had in getting out of box K will be remarked. The curve is interrupted twice, which indicates two failures. It is,

tinguished from the idea of the act done or to be done. It is not the motive that leads the animal to do the act; it is the consciousness itself of the performance of the act. There is in it a psychological element and a physiological element. The "impulse" is the feeling which comes from seeing oneself move, from feeling one's body in a different position, etc.—a position which relates to the execution of a particular act and which characterizes it; it is the consciousness of the kinæsthetic sensations that result from that attitude. Equivalent expressions would be—the feeling or consciousness of movement; the feeling of muscular effort.

besides, extremely irregular; after remaining low for some time it suddenly rises at the end of the first series of experiments. The curve carried on the same line of abscissas, showing the results of a new series of attempts after quite a long interval, shows that association was still far from being definitely formed; altogether it shows a very decided agitation and disorder of mind in the subject.

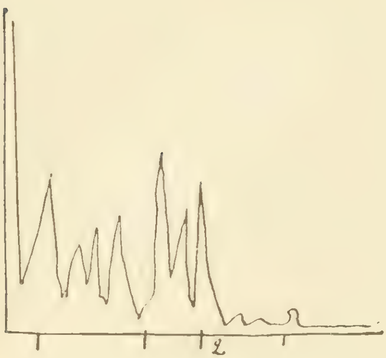


Fig. 5.—Cat No. 5 in box K. (Thorndike, p. 22. Formation of association.)

The behavior of dogs was in a general way quite different from that of cats.

A dog who, when hungry, is shut up in one of these boxes is not nearly so vigorous in his struggles to get out as is the young cat. And even after he has many times experienced the pleasure of eating on escape he does not try to get out so hard as a cat, young or old. He paws or bites the bars or screening and tamely tries to squeeze out. He gives up his attempts sooner than the cat if they prove unsuccessful. Furthermore, his attention is taken by the food, not the confinement. He wants to get to the food, not out of the box. So, unlike the cat, he confines his efforts to the front of the box. It was also a practical necessity that the dogs should be kept from howling in the evening, and for this reason I could not use as a motive the utter hunger which the cats were made to suffer. In the morning, when the experiments were made, the dogs were surely hungry, and no experiment is recorded in which the dog was not in a state to be willing to make a great effort for a bit of meat, but the motive may not have been even and equal throughout, as it was with the cats.[a]

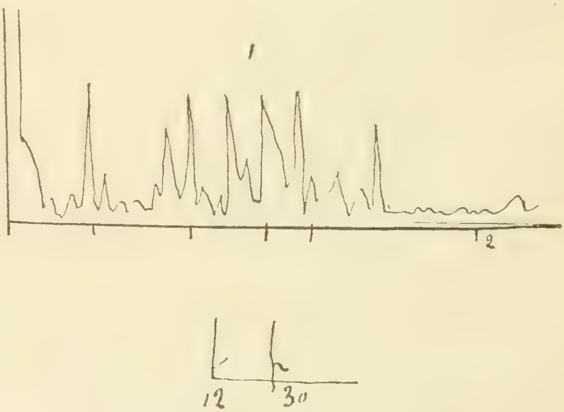


Fig. 6.—Cat No. 3 in box G. (Thorndike, p. 21, Memory.)

An examination of the curves for these experiments shows a rapid descent, generally after the second trial, sometimes after the first. Above all. there is recorded in a much less degree the sharp elevations indicating duration. In order to show the contrast, we reproduce the curve relative to cat No. 10, from 4 to 8 months old, and dog No. 1 placed in two similar boxes, C and C C, closed by a button which had to be brought from a vertical to a horizontal position in order to open the box. The same remarks apply to the curve

[a]Thorndike, pp. 32 and 33.

of dog No. 1 in box O, similar to box K in which was shut cat No. 3. Apart from an abrupt rise in the curve followed by an immediate descent, we see no such marked irregularity, and, in particular, we see no interruption; that is to say, no failure.

The experiments made with chickens were arranged in a little different manner. The subject was placed in a pen with two exits, one of which led to the place where were the other chicks and food, the other to a second pen from which there was no issue. The number of these false exits could be arbitrarily increased. There were other pens in which an obstacle was placed in the chicken's path, a few steps to climb, a piece of stovepipe, 11 inches long, forming an inclined plane which led the subject to an open platform from which the animal could jump down among his companions. In other cases he could escape by pecking at the door of the cage, by climbing up a spiral staircase and out through a hole in the wall.

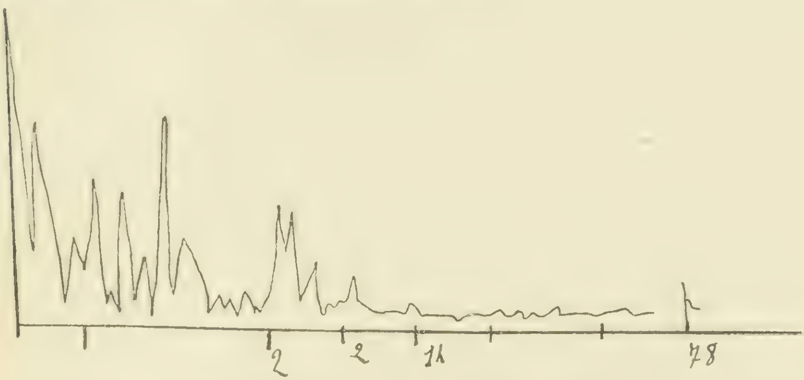


FIG. 7.—Cat No. 10 in box C. (Thorndike, p. 19, fig. 3.)

Everything being equal, and making allowances for the modifications due to the influence of heredity, the behavior of the chicks shows the same general character as that of the cats. The subject first shows extreme agitation. Its conduct appears to be governed by the law which may henceforth be considered as having a universal application: "An animal shut up and isolated tends to execute, for the purpose of getting out, all the acts which ordinarily give him his liberty under analogous conditions."[a] The alternation of successes and failures produces a selection; it is the pleasure that attends the successful act or series of acts that causes it to survive.

Chickens are, in general, slower in forming associations than the animals previously considered. Our author explains this by a difference in their bodily organs and instinctive impulses. The anatomical and physiological constitution of the chicken is on a lower plane than

[a] "In scientific terms this history means that the chick, when confronted by loneliness and confining walls, responds by those acts which in similar conditions in nature would be likely to free him." Thorndike, p. 36.

that of the dog and cat: its hereditary tendencies, derived from physical conditions, are less suited than are those of the dog or cat to permit a prompt reaction to the definite impressions of these experiments. On the other hand, it is not very easy to distinguish, in the behavior of two species of animals, the part played by individual intelligence and that taken by heredity, race, etc. We have not here any precise indications which would permit us to class, finally, these animals in the scale of intelligence; the problem can only be solved by complex researches upon the development of attention, memory, activity, etc. The present experiments enable us to say, however, that the chicken ranks below the dog and the cat and that, as to these, the dog generally appears as the more intelligent.

Fig. 8.—Dog No. 1 in box C C. (Thorndike, p. 33, fig. 11.)

IV.

Experiments concerning imitation and the psychological life of animals.—To the question, "Do animals imitate?" science has uniformly answered, "Yes." But, put in this way, the question is too general; there are several kinds of imitation, not a single species.

There are, to begin with, the well-known phenomena presented by the imitative birds. The power is extended widely, ranging from the parrot who knows a hundred or more articulate sounds to the sparrow whom a patient shoemaker taught to get through a tune. Now, if a bird really gets a sound in his mind from hearing it and sets out forthwith to imitate it, as mocking birds are said at times to do, it is a mystery and deserves closest study. If a bird, out of a lot of random noises that it makes, chooses those for repetition which are like sounds that he has heard, it is again a mystery why, though not as in the previous case a mystery how, he does it. The important fact for our purpose is that, though the imitation of sounds is so habitual, there does not appear to be any marked general imitative tendency in these birds. There is no proof that parrots do muscular acts from having seen other parrots do them. At any rate, until we know what sort of sounds birds imitate, what circumstances or emotional attitudes these are connected with, how they learn them, and, above all, whether there is in birds which repeat sounds any tendency to imitate in other lines, we can not, it seems to me, connect these phenomena with anything found in the mammals or use them to advantage in a discussion of animal imitation as the forerunner of human.[a]

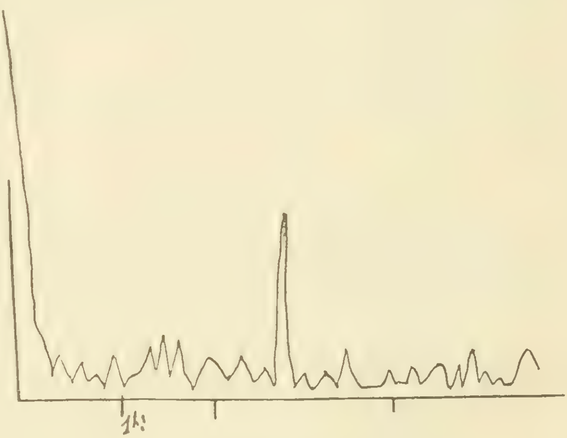


Fig. 9.—Dog No. 1 in box O. (Thorndike, p. 34, fig. 12.) Compare curve of cat 3, in box K, supra.

[a] Thorndike, loc. cit., p. 47.

Another sort of imitation ought also to be eliminated—that shown, for example, in a flock of sheep. The first ones leap over a barrier which is taken away before all the flock have passed; the next sheep jumps as if to get over a barrier, although it is not there, and five or six others do the same. In appearance—but only in appearance—this is a phenomenon of imitation. In fact, the reproduction of the act accomplished by the first animals may depend upon very special circumstances peculiar to animals that live in flocks. "It is possible that among gregarious animals there may be elaborate connections in the nervous system which allow the sight of certain peculiar acts in another animal to arouse the innervation leading to those acts, but that these connections are limited. The reactions, according to this view, are specific responses to definite signals, comparable to any other instinctive or associational reaction. The sheep jumps when he sees the other sheep jump, not because of a general ability to do what he sees done, but because he is furnished with the instinct to jump at such a sight, or because his experience of following the flock over bowlders and brooks and walls has got him into the habit of jumping at the spot where he sees one ahead of him jump; and so he jumps even though no obstacle be in his way.[a] There is present at the same time a phenomenon of hereditary instinct and of personal experience. Primitively, the sheep who now imitates did not jump unless the external elements calling for that act were present and especially unless the obstacle was present; now he jumps "when only the nonessentials are present."[a] Besides, "these limited acts may be the primitive, sporadic beginnings of the general imitative faculty we find in man." In any case, the very fact that diverse interpretations are possible obliges us to leave out of consideration this kind of imitation in the present investigation.

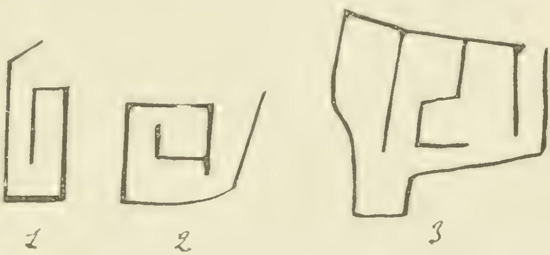


FIG. 10.—Labyrinths used in experiments with chickens. (Thorndike, p. 35.)

The imitation which we are to study here must be imitation in the precise and strict sense of the word, understood as the transfer to one's own personality of an association formed by another.

V.

1. *Experiments with chickens.*—Two chickens, Nos. 64 and 66, were shut in a cage from which one could get out only by crawling under the wire screening at a certain spot or by walking up an inclined plane

[a] Thorndike, loc. cit., p. 49.

and then jumping down. No. 64 had been previously taught to get out at the hole. No. 66 had no experience with the two methods of exit. After 9 minutes 20 seconds, No. 66 went out by the inclined plane, although No. 64 had in the meantime crawled out under the screen 9 times. It was impossible to judge how many times No. 66 really saw No. 64 do this. He was looking in that direction 5 times.

Similar experiments were made with other chickens, utilizing other methods of exit indicated above—pecking at the door, jumping on a little platform, etc. Certain ones especially may be mentioned which were made with 8 chickens (Nos. 80 to 87) ranging in age from 16 to 30 days. Each was put in and left alone from 60 to 80 seconds, then another was introduced who knew the means of exit. The experiments were numerous. Chicken No. 80, for example, saw his companion go out 54 times; he failed completely, notwithstanding the long duration of the attempt (60 minutes). There was but one exception, No. 82, who finally escaped at the end of 8 minutes 40 seconds; the method of escape was effected by stepping upon a platform; and the author considers that in this case the successful attempt was purely accidental. The conclusion reached, then, is that these animals do not imitate.

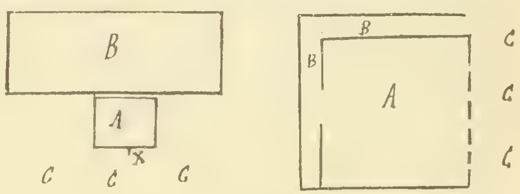


FIG. 11.—Imitation in chickens.

2. *Experiments with cats.*—The box used for these experiments was arranged in two compartments separated by a wire screen. The larger of these had a front of wooden bars, with a door which fell open when a string stretched across the top was bitten or clawed down. The smaller was closed by boards on three sides and by the wire screen on the fourth. The subject was placed in the latter compartment. The cat who was to serve as guide was placed in the other. The subject could in this way observe his guide, see him pull the string, go out, and eat the fish. Record was made of the time during which the subject was looking at his companion. The latter, at fixed intervals—48 hours, 24 hours—repeated a certain number of times the act of going out. Then the subject was in his turn placed in the large compartment from which he was to attempt to get out. The time elapsing between his entry and the moment of his pulling the string was noted. If he failed in 5 or 10 or 15 minutes to do so, he was released and not fed.

As regards their general behavior, it is to be noted that the cats that here served as subjects behaved exactly as those did who were put in the same position without ever having under their eyes a companion as a model. They struggled as usual without ever noticing the liberating string. The example of the cat used as a guide was of

no utility; the association was formed in the same way as if each had been placed alone in the box.

Besides, one would expect that if the association between the sight of the string and the act which results from pulling it had been formed by seeing the guide cat pull the string the subject would pull at the string as soon as he saw it; or, if there was a slight hesitation, a little indecision, such a period would be extremely short, at least it would be nearly constant for all subjects. Now, none of these expectations was fulfilled. No subject pulled the string on being placed in the compartment. The only exception was merely an apparent one—No. 6, in the midst of irregular struggles to get out, chanced to hit the string with its paw. The association between pulling the cord and the act of getting out was so slight that he remained in the box for 16 seconds before he noticed that the door was open. Cats No. 7 and No. 5 always failed, notwithstanding the fact that they fixed their attention upon the guide cat in an unmistakable manner 43 and 33 times, respectively, and in a doubtful manner 111 times for No. 7 and 68 times for No. 5.

No. 3 alone succeeded very promptly in getting out in three experiments, and in 3 minutes and 30 seconds. He finally succeeded in 8 seconds; but it should be noted that imitation was not necessarily a factor, for this cat showed in the course of numerous experiments signs of a much more lively intelligence than the others. He probably got out by his own effort alone. Besides, when a subject gets out of the box, if the success was due to imitation there ought to be a regular relation between the time which he observed his guide and the time employed in getting out; the latter should be in inverse proportion. Yet it is the opposite that is observed—the longer the time of observation the more time was lost in efforts to get out, or, indeed, the attempt ended in complete failure.

VI.

If the experiments are varied the same results are reached. For example, two cats were placed in the same cage, one of which, unacquainted with the means of exit, sees the door opened and goes out and is fed with him. The experiment is repeated a number of times, then the subject is placed in the box alone. No modification of his behavior is noted which reveals the influence of imitation; the association is formed no quicker; the method employed was different from that used by his companion. Cat No. 1 opened the door by pulling at a loop with his teeth; cat No. 7, the subject, pulled it with his paw. In another box which could, at the will of the animal, be opened in two ways cat No. 3 pulled at a loop at the back of the box, while cat No. 5 pulled a string at the front.

3. *Experiments with dogs.*—From these, too, it appears certain "that the animals were unable to form an association leading to an act from having seen the other animal or animals perform the act in a certain situation. Not only do animals not have associations accompanied, more or less permeated and altered, by inference and judgement, they do not have associations of the sort which may be acquired from other animals by imitation."[a] Imitation can not in the animal take the place of reason, since it does not even exist. "If a general imitative faculty is not sufficiently developed to succeed with such simple acts as those of the experiments quoted, it must be confessed that the faculty is in these higher mammals still rudimentary and capable of influencing to only the most simple and habitual acts or else that, for some reason, its sphere of influence is limited to a certain class of acts possessed of some qualitative difference other than mere simplicity which renders them imitable."[b]

Another point in this question of imitation was brought out in the experiments with dogs. It was wished to ascertain, not whether imitation could facilitate the execution of an act which the subject could have performed, though less easily, by himself alone, but whether imitation could bring him to accomplish an act too difficult for and superior to his personal resources.

Two dogs, Nos. 3 and 1, were placed in two identical boxes set face to face opposite each other, so that No. 3, himself incapable of opening his box, saw by what movement No. 1 let himself out. The result was a complete failure. The experiments were repeated five times at intervals of 1 hour, 24, and 48 hours. No. 3 certainly saw No. 1 go out 66 times, and probably saw him 93 other times. Finally, left to himself for 40 minutes, he could not accomplish the necessary act. The conclusions derived from other analogous experiments are exactly the same. Dog No. 1 had learned to release himself from a box by jumping up and biting a cord. Dogs 2 and 3 were brought in. Like him, they jumped and bit, scratched here and there with their claws, but they never jumped after the cord. Dog No. 2 was tried with this series of experiments 8 times; he saw No. 4 get out 70 times, yet he never succeeded in imitating him. No. 3 was tried 9 times at intervals of 1 hour, 24, and 48 hours; he certainly saw No. 1 bite the cord and escape 75 times; his want of success was the same.

VII.

The conclusion finally reached, that animals no not imitate, seems contrary to the opinion of certain animal trainers interrogated by the author; but the facts appear to warrant this conclusion.

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[a] Thorndike, pp. 61, 62. [b] Thorndike, loc. cit., p. 62.

We give below some of the opinions of these trainers. They do not all agree, and besides they do not in any way impeach the very precise and scientific experiments of Mr. Thorndike.

Question 1. If you wanted to teach a horse to tap seven times with his hoof when you asked him, "How many days are there in a week?" would you teach him by taking his leg and making him go through the motions?

A answered, "Yes, at first."

B answered, "No; I would not."

C answered, "At first, yes."

D answered, "No."

Question 2. Do you think you could teach him that way, even if naturally you would take some other way?

A answered, "In time, yes."

B answered, "I think it would be a very hard way."

C answered, "Certainly I do."

D answered, "I do not think I could."

E answered, "Yes."

Question 3. How would you teach him?

A answered, "I should tap his foot with a whip, so that he would raise it, and reward him each time."

B answered, "I should teach him by the motion of the whip."

C answered, "First teach him by pricking his leg the number of times you wanted his foot lifted."

E answered ambiguously.[a]

Let us compare the investigations of Mr. Thorndike with observations made on the inhibition of instincts by habit.

This phenomenon, very frequent among animals, has been noted by previous psychologists, and notably by William James in his Psychology. In this the animal, being able to perform two acts, one of which is simple and natural, the other imposed by habit, chooses the latter. In the boxes which Mr. Thorndike used the hole by which the animal was introduced was usually covered, so that it was obliged to go out at the door. Yet, after the association was once formed, even if the hole was left uncovered, the animal continued to go out at the door, although the opening of the latter was more difficult for it.

The influence of association upon the inhibition of instincts may be exerted in two ways. Sometimes the instinct may wane by not being used; sometimes it is inhibited for the moment by a contrary disposition. An instance of the former sort is found in the history of a cat, which, when placed in a box like those we have indicated, learns to open a door and escape. After enough trials, the board covering

[a] Thorndike, loc. cit., pp. 71, 72.

the entrance hole is removed. The cat will still continue to open the door, but if at any time she happens to notice the hole she may make use of it occasionally, but not invariably. An instance of the second sort is that of a chick placed in a cage, A, separated by a wire screen from a box, D, in which were other chickens and food. After picking and scratching at the screen, the subject finally jumps to B, and, after a similar process, to C, then reaching D. After seventy-five or eighty trials the wire screen is removed. The chicken could now at will descend from A to D, or from B to D, or from C to D. Now, this singular phenomenon appears: He goes to the edge of A, looks down upon his comrades, but does not jump down into D, although nothing prevents him, and then goes into B, where he does the same. Finally, in spite of the removal of the screen, the chicken traverses the long route A, B, C, D. The instinct has been truly inhibited. The author observed but one case in which, after the wire was removed, the chicken, after looking over nine times to see his comrades, decided, after seven minutes, to jump directly into D.

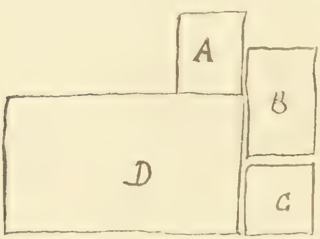

Fig. 12.—Inhibition of instincts by habit (chickens).

VIII.

We can now attempt to make an outline of the conception of the psychological life of animals as derived from these investigations.

That life is, take it altogether, rather meager. The animal is not endowed with reason; the faculties of comparison and conception of similarity are wanting. He lacks ideas and tendencies which would, as a whole, constitute an original and free intellectual life; he has no memory of the past in the sense of a superior faculty by which he can recall at will psychological states that have disappeared, for the purpose of comparing or contrasting them with present states. The phenomena of association that constitute his mental life, while presenting a certain analogy with some human associations, remain very different from what they are in man.

The animal lacks entirely the power not only of correlating ideas independent of a corporeal attitude and determinate exterior conditions, but also of varying, of combining associations originally formed under external influences. We should not, however, conclude from these investigations that the three species of animals here experimented with necessarily represent the totality of animals. It is especially notable that Mr. Thorndike has been unable to investigate monkeys. A similar study of these animals is much to be desired.

The experiments here cited may at least aid us in establishing a criterium of the difference between animal and human intelligence. According to a widespread opinion, held especially by Mr. C. L.

Morgan, the difference between these two kinds of intelligence consists simply in the greater complexity or simplicity of their association. The superior animals are supposed to be capable of constructing concepts more or less similar to our own, the association being the same both in them and in man. The aptitude for forming rich and complex associations constitutes intelligence, properly so called, as opposed to reason defined as a faculty of analysis. From the point of view of intelligence there is a regular gradation from man to the animal. That which distinguishes them is the presence of that rational analytic faculty with which the faculty of speech is connected. We also meet men in whom that analytic faculty is but slightly developed and who nevertheless show a high degree of intelligence. In the human species these individuals are those whose mental life most closely approximates to that of the superior animals; there is an almost direct transition from one to the other.

This theory can not be accepted. Human association is entirely transformed by the intervention of inference, judgment, and comparison. It includes imitation, understood as a transferred association. Its elements may exist in our consciousness in an isolated manner, independently from the primitive association that united them, etc. Our author says in plain terms that "man is no more an animal with language than an elephant is a cow with a proboscis."[a] The species or genera should be no more confounded from the psychological than from the physiological point of view.

Progress from the psychological life of the animal to the mental life of man has been effected by transforming the direct connections between the terms of an association into indirect ones. It is essential to understand that an animal has not a continuous and free mental life. Its consciousness does not control the multiple series of associations which his life obliges him to form. Living in the present, his mind is powerless to grasp the past or to previse the future. He possesses only a fragmentary consciousness whose various elements are interconnected only in a confused manner; at each instance of time the ego of the animal is made up of the consciousness of an association directed with a view to an immediate practical action, an association whose terms are directly united, under the pressure of exterior circumstances; there is no continuity imposed from within. With man, on the contrary, the elements of an association may be dissociated and isolated one from the other; they are not indissolubly bound up with the excitation that caused their appearance in consciousness, and with the reaction which responded to that excitation. There is thus a series of terms, very variable in number, but always considerable in each individual consciousness, which play freely, associating themselves with

[a] Thorndike, loc. cit., p. 87.

each other in an original and independent manner. By memory, generalization, inference, etc., faculties properly human, the elements of past associations intervene in the play of the present elements, and this total may be organized with reference to a future action. An important investigation for comparative psychology would consist in attempting to find in the child and in the most elevated types of the primates the first traces of this transformation of directly practical association into a free and continuous mental life. We should thus be able to ascertain, not the legendary account, but the real history of the origin of our human faculty of association.

"Our work," says Mr. Thorndike, "has rejected reason, comparison, or inference, perception of similarity, and imitation. It has denied the existence, in animal consciousness, of any important stock of free ideas or impulses, and so has denied that animal association is homologous with the association of human psychology. It has homologized it with a certain limited form of human association. It has proposed, as necessary steps in the evolution of human faculty, a vast increase in the number of associations, signs of which appear in the primates, and a freeing of the elements thereof into independent existence. It has given us an increased insight into various mental processes." It has convinced the writer, if not the reader, that the old speculations about what an animal could do, what it thought, and how what it thought grew into what human beings think, "were a long way from the truth, and not on the road to it."

I believe that our best service has been to show that animal intellection is made up of a lot of specific connections, whose elements are restricted to them, and which subserve practical ends directly, and to homologize it with the intellection involved, in such human associations as regulate the conduct of a man playing tennis. The fundamental phenomenon which I find presented in animal consciousness is one which can harden into inherited connections and reflexes, on the one hand, and thus connect naturally with a host of the phenomena of animal life; on the other hand it emphasizes the fact that our mental life has grown up as a mediation between stimulus and reaction.[a]

Theoretical science may derive a profit from these conclusions; but the author thinks also that from all these investigations some of the results possess considerable pedagogical interest. The associative process requires the immediate personal experience of the animal. Why not apply this psychological proceeding to the education of the child? There are young minds that have not, at first, the theoretical intelligence for certain matters of knowledge that are taught, such, for example, as mathematical operations; often the teacher's theoretical explanation escapes them. Why not, in this case, have recourse to practical and personal "training?" Pedagogical methods founded on imitation can not affect certain minds; for them the best

[a] Thorndike, loc. cit., pp. 108, 109.

method of learning long division, for example, would perhaps be to learn it in the form of numerous practical exercises. This method, like that of animal trainers, is founded on the formation of association by the repetition of the act. One of the essential laws of pedagogy ought to be that no restraint should be imposed upon children that is not based upon the subjective laws that govern the personal development of each child.

IX.

The method of investigation chosen by Mr. Thorndike has the great advantage of including in the observation only known elements, chosen in advance by the observer himself; it simplifies and makes clear the data of the crude experiment; it facilitates the interpretation of facts. Yet it is necessarily somewhat arbitrary; it neglects the actually existing complexity. In the investigations considered, one single element, of a physiological rather than a psychological nature, dominated the conduct of all the subjects—that is, hunger. But is that state of physiological disturbance the most favorable one for studying the superior psychological life of animals? In studying states of consciousness closely associated with a physical need, has not Mr. Thorndike purely and simply eliminated in advance an entire side of that intellectual life, and precisely those forms, rudimentary without doubt, but perhaps really existent, of an original and free psychological development?

Everyone knows how much our own mental life may be disturbed and upset by a disorder affecting an organic function. Notwithstanding the authority of Pascal, we are generally but little inclined to mathematical calculations while suffering with the toothache; poetic revery is not a common preoccupation of a man who is hungry. Now, other things being equal, was not this state of mental depression, which is intimately allied to physical suffering, the state in which Mr. Thorndike's subjects, particularly his dogs and cats, were placed? A single feeling engrossed their consciousness—the feeling of the distress they suffered; it was like a state of mono-ideism which must disturb the normal course of their psychological development. The procedure of Mr. Thorndike appears to us very acceptable as regards the investigation of the conditions of the formation and nature of association—at least, in so far as he defines it—but it yet is necessary to complete the investigation by a study of subjects, free, as regards physiological necessities.

As to the investigations regarding imitation, they seem to us much less conclusive. In the first place, Mr. Thorndike reasons as if the time during which the subject looks at the model corresponded to a time of real attention. Nothing could be less certain. Even when the subject sees the cat or the dog taken as guide escape from the cage, his own consciousness may be occupied by quite other matters

than the care of observing and retaining the movements accomplished by that guide. It is then that the consciousness of physical discomfort becomes an obstacle to the development of psychological life. Doubtless the subject could have but one desire, that of getting out as soon as possible; but in order to give real attention to the acts of his comrade, to organize them into precise memories, the animal should be disembarrassed from the consciousness of physical suffering, which, however, does not leave him for an instant. He should be capable of the intellectual effort, anticipating the future and representing to himself the series of movements going on before his eyes as being the condition of his own deliverance. If the time the animal takes to escape does not, then, vary in inverse proportion to these supposed observations, it is not because the animal is absolutely incapable of imitating; it is because he has given no real attention. In order to put out of his consciousness the painful feeling of hunger that controls him and to impress upon his mind the consecutive acts of his guide, he must have a control over himself that is not possessed by any animals. It would, above all, be necessary for the subject to comprehend that these acts and movements were the only ones that lead to deliverance. But can we ask of an animal such an effort of intelligence and foresight?

Let us now consider the moment when, his guide having got out, the subject is, in his turn, placed in that part of the cage. The state of hunger that tortures it being present, what feeling can occupy its mind? Mr. Thorndike takes for granted that if the animal imitates he ought to execute in order the movements that he has seen accomplished by the other subject. But nothing could be more contestable. The animal is already discontented from having been shut up; instead of being out, his suffering is now prolonged; the changing of his compartment has given him a momentary illusion of approaching liberty; now here he is again with the doors all shut. He inevitably becomes angry, and this new discontent is shown by the agitation, sometimes quite excessive, which the author has noted. If the subject had at first some tendency to reproduce the acts of the model, such tendency would be immediately obliterated by this brusque display of activity, the expression of his irritation. The cat and the dog do not immediately open the door, not only because they are incapable of judging as to the efficacy of their various movements, but also because the memory of acts accomplished before them is not sufficiently powerful to repress this overflow of useless action which arises from their anger; and when that anger has passed, the memory of these acts is already too distant to be utilized. This does not at all prove, however, that under more favorable conditions imitation would not take place; perhaps, indeed, the study of the play of animals might lead to conclusions different from those of Mr. Thorndike.

It also appears to us that Mr. Thorndike's definition of imitation is rather a narrow one; starting from this definition he concludes that imitation does not exist among animals. According to him, in order that there should be imitation the subject must exactly reproduce the same movement, the same gesture that he has seen. So (see text) cat No. 7 did not imitate cat No. 1, because the latter opened the door by pulling a loop with its teeth, while No. 7 pulled it with its paw. It seems to us, however, that the exact, complete reproduction of a movement is an example of imitation that is relatively difficult and quite complex; it is the perfect form of imitation, very common with man, who possesses a developed imagination. There may be some exaggeration in expecting to find it as perfect as this among animals. The subjects of Mr. Thorndike have not reproduced the movements of their model because they did not possess a sufficiently strong or lively faculty of representation. The experiments cited by us may likewise be interpreted otherwise than is done by the author. The point was to see whether the animal, guided by the author, would repeat the movement which the latter made him execute. It was required to open the box C, closed by a button. It was shown that the subjects did not turn the button in the way they had been taught: they did not repeat identically the act which it was desired to teach them. But the essential matter is that there was formed in their consciousness the notion, even though vague, of a relation between the situation before them and the act of turning the button. Each subject would then translate this relation in a manner personal to himself—one would push the button with his nose; another would bite it, etc. In brief, we would not have an exact reproduction of the movements which had been taught—there would not be a perfect imitation; but the question remains unaffected, whether the primary, rudimentary form of imitation does not consist, in the experiments here cited, merely in a connection between a given situation and a possible direction of movements. The button of the door does not appear to the subject as the central point on which the action depends; progress in imitation will consist in associating with the point the image of the special movements executed by the animal that served as model. We must expect to find in them a trace of imitation, a tendency still vague in its manifestations, rather than a clearly established habit. The disadvantage of Mr. Thorndike's method appears to us to be that he has transported into the domain of animal psychology the notion of imitation defined according to human examples. Unwittingly, Mr. Thorndike has not escaped the prejudice that consists in observing animals with preconceptions derived from the normal psychology of man. In this very question of imitation the problem appears to us to be that of seeking within the animal series to find what acts, what

movements, may imply a tendency to imitation, what forms of imitation are met with among the superior animals—not to seek to know whether animals imitate as men do, or if they have the same imitative processes that we have.

In spite of these few objections, the merit of these investigations appears very great. The method which is here inaugurated and the new views derived from them have already suggested other studies. As to the author himself, this beginning is full of promise, and we hope, in the interest of experimental psychology, that this promise will bear more fruit.

ANIMALS THAT HUNT.[a]

By Henri Coupin.

The nimrods who, armed from head to heel, are going forth in a few days to contend with terrible partridge chicks and frightful rabbits may not be aware that their methods of hunting are in use among animals. For the benefit of those who are perhaps ignorant regarding this fact we will explain.

The toxote, for example, a fish in the rivers of Malaysia, has learned how to shoot at a mark and well deserves its name of the archer, or the spitting-fish, which has been given it. Although aquatic it feeds upon winged insects. When it sees on the plants on the bank a silly insect gaping in the air it advances as near as possible to the object of its desires, fills its mouth with liquid, and closes its gills. Soon it raises its snout out of the water and, closing its jaws, shoots upon the insect a long thread of water—a veritable shower bath—which, falling back, washes the poor creature into the river, where he has not long to wait to be devoured. The remarkable part of this performance is the accuracy of the fish's aim which very rarely misses. In Java and the neighboring countries people often carefully preserve the toxote in aquariums and amuse themselves by offering it flies, holding them some distance off so that it will shoot at them with its douche, to the great delight of the spectators.

To obtain food another fish, the chelinous, proceeds in the same way with salt water, but he is less adroit, a fault which he possesses in common with many hunters. Yet he is always persevering. If he misses his aim he tries again until he succeeds, unless the insect has withdrawn out of reach.

Lying in wait for prey is practiced with great skill by a large number of animals who have learned that in order not to frighten away the creatures which they wish to catch it is necessary to remain motionless. This is notably the case with crocodiles, which wait whole days without moving, hidden in the water or the grass on the shore, until their prey, deceived by their apparent quiet, comes to bathe or to slake his thirst. It is also the case with the python snake,

[a] Translated from the Revue Scientifique (Paris), August 29, 1903, pp. 274–277.

that waits hanging from the trees by his tail so immovable that he can not be distinguished from the surrounding branches. When an animal is about to pass he lets himself fall upon it. Various leeches in Africa proceed in the same manner. In passing through virginal forests only too frequently one hears a sudden noise like hail falling on the branches. It is not falling hail, but leeches which hasten to attach themselves to beasts of burden and to men, from whom they hasten to suck the blood. They were watching their chance, perched on the branches—an odd dwelling place, by the way, for creatures that are generally considered aquatic.

The bird of prey called the Pygargus sea eagle also waits till his victim comes within range. Audubon has picturesquely sketched him. "Behold," says he, "just at the bank of a great river the eagle, perched upright on the last branch of the highest tree. His eye, glittering with a somber fire, sweeps over a vast stretch. He listens, and his subtle ear is open to every distant sound. From time to time he casts a glance downward to the earth for fear lest even the light step of the fawn may escape him. His female is perched on the opposite bank, and if all remains tranquil and silent she admonishes him, by a cry, still to be patient. At the well-known signal the male partly opens his immense wings, bends his body slightly downward, and answers her with another cry like a burst of maniac laughter. Then he resumes his upright position and again all is silent. Ducks of all sorts, teals, scoters, and others pass before him in swift flocks and descend the river, but the eagle does not deign to notice them; they are not worthy of his attention. Suddenly like the hoarse note of a clarion the voice of the swan resounds, still distant, but coming nearer. A piercing cry comes across the river from the female, not less active, not less alert than her mate. He shakes all his body violently, and by several shakes of his head, aided by the action of the muscles of the skin, he in an instant arranges his plumage. Now the white voyager is in sight. His long snowy neck is stretched forward; his eyes are on the alert, vigilant as those of his enemies. His great wings seem to support the weight of his body with difficulty, though they beat the air incessantly. He seems so wearied in his movements that his legs are even stretched out under his tail to aid his flight. At the instant when the swan is about to pass the somber pair the male, fully prepared for the chase, darts down uttering a formidable cry. The swan hears it, and it sounds more terrible to his ears than the report of the murderous gun. This is the moment to appreciate the power which the eagle puts forth. He darts through the air like a falling star, and swift as light swoops on his trembling victim, who in the agony of despair tries by various evolutions to escape from the embrace of his cruel talons. He pretends death, makes feints, and would even plunge into the current. But the eagle prevents him; he

has known too long that by this stratagem his prey could escape, and he forces him to remain on the wing by trying to strike him from beneath."

The beautiful bird that is known to all as the bee eater proceeds like those hunters who, on the shores of the Mediterranean, watch for game on its return from Africa. He posts himself near a nest of wasps or bees and snaps up these little stiletto bearers as they come out or return home.

The baudroie prefers to catch by decoy. This rather large fish buries himself in the mud and lets only a sort of small flag appear, which is fastened to his nose by the medium of a long filament which floats as the water moves it. The little fishes in his neighborhood hurry toward this flag, thinking they have to do with an easy prey. When they are gathered in goodly number, disputing over this sweet morsel, the baudroie opens his huge mouth and swallows them down without further ceremony.

Other animals are more refined and, in the hunt by decoy, prefer to use traps. It might be supposed that this method of hunting, which demands a certain intelligence, would be practiced by creatures of rather high organization. This is not so, since the humble insects employ it. The larva of the ant-lion digs on the surface of the sand a large funnel, at the bottom of which he crouches; every insect which tries to pass roils down into the funnel and reaches the bottom, where at once it is snatched up by the larva. This is pit hunting. Moreover, if the victim seems likely to escape, he shovels at him quantities of sand which makes him fall still more quickly. The larva of cicindela acts differently, but with equal craft, in order to obtain the little insects necessary for his nourishment. He digs in the earth a vertical hole, in which he props himself like a chimney sweep climbing up a chimney, in such fashion that his head, flattened and slightly hollowed, exactly stops up the orifice of the opening on a level with the ground. When a little creature is about to pass over this veritable living trap the larva sinks down, at the same time dragging with him his victim, which he hastens to seize between his claws and to devour.

Hunting with the aid of nets is, as we know, practiced with great ability by spiders, who stretch their webs, which are sometimes irregular, sometimes of marvellous regularity, in our gardens and houses. Some await their prey, keeping to the middle of the web. Others, more prudent, hide in a little silken cell well concealed in a hole of the wall. Most of them trust to the strength of their threads and to the glutinous substance with which these are moistened. When a victim is taken, the spider often prevents it from struggling by enveloping it with delicate threads. If it is small, however, he contents himself with killing it and sucking it up on the spot or after

dragging it into a corner. There exists in Madagascar a spider which, for a long time, puzzled the naturalists. Its web is rather like that of our *Epeira diademis*, but it is noticeable that at the center there is a great thread of silver white, a veritable cable, bent in zig-zag. What could possibly be the use of this? One could watch the web for a long time without seeing the creature make use of it; when a victim is taken, the spider is content to wind him about with small threads. Yet the cable is undoubtedly of use to the spider, for if it is removed he hastens to make another. M. Vinson at last, after long observation, succeeded in solving the question. One day when he was examining for the hundredth time the tricks and the manners of the spider, he saw a great grasshopper jump into the midst of the web. At the same instant the spider, darting upon the cable, began with the greatest swiftness to wrap it about the insect. The victim was too large to be held by the simple threads; the cable was there to bind him securely.

The ant-eater depends less on the power of skill, and, like a child, limes his game. He puts out his long sticky tongue and flattens it on the ground; all the insects that pass stick to it, vying with each other, and when the heap is sufficiently thick, the ant-eater draws his long tongue in and swallows them all. At other times he plunges his lingual appendix into ant-hills and draws it back laden with ants.

Coursing is very frequent among mammals, notably among wild dogs, wolves, and foxes. According to F. Houssay, wild dogs follow their prey in immense packs. They excite one another by their bayings at the same time that they frighten the game and half paralyze its power. No animal is agile nor strong enough to be sure of escaping them. They surround him and cut off his retreat in a most skillful manner; gazelles, antelopes, despite an extreme lightness and swiftness, are overtaken at last; wild boars are quickly run down; their rough defense costs some of the assailants their life, but these also become the prey of the pack that falls upon the quarry. In Asia these wild dogs are not afraid to attack even the tiger. Many, without doubt, have their backs broken by a blow from his paw, or are strangled by being seized by his jaws, but the death of comrades does not diminish either the courage or the hunger of the surviving assailants. Their number is such, moreover, that the great beast, overrun, covered by agile enimies who cling to him and cover him with wounds, finally succumbs.

Wolves likewise hunt in large packs. Their boldness, when hunger presses them in the bad season, is well known. In time of war they follow army corps to attack stragglers and devour the dead. In Siberia they follow sledges on the snow with a redoubtable perseverance and the pack is not restrained by the corpses of their comrades who are shot down. Aside from these fatal battles, wolves seem to

have the power of combining for actual stratagems. Sometimes a pair hunt together. If they meet a flock, knowing that the dog will defend bravely the creatures intrusted to him, that he is vigilant, and that his fine sense of smell will bring him upon them long before the herdsman is aware of them, they attend first to him. The wolves approach, warily keeping out of sight; then one of them abruptly shows himself and attracts the attention of the dog, who rushes upon the wolf and pursues it with such eagerness that he does not perceive that, during this time, the second thief has seized a sheep and dragged it into the wood. The dog finally gives up his attempt to vie in swiftness with the fugitive and returns to his flock. Then the two confederates again meet and share their prey. In other cases a wolf will hunt with his mate. When they wish to take a roebuck, one of the pair—the male, for example—follows it and directs the chase so as to make the prey pass near a place where the female is hidden. She then springs forward and continues the chase while the male wolf rests. It is a veritable organized relay race. Of necessity the strength of the roe is exhausted, and he can not equal the ardor which his pursuer, quite fresh, displays in the chase. He is taken and put to death. The male has meanwhile approached the place of the feast in a more leisurely manner and comes to claim his share of the booty.

By what we have now said, it is clear how analogous to our own methods of hunting are those which are in use among animals. That the picture may be complete, it is necessary to cite the poachers, which will not be difficult, for they are legion. I will only mention one of them—the most audacious—the stercorarius, a sea bird that is often seen on the seashore following gulls, sea mews, and terns as if he would devour them. Such is not his purpose. If you follow him with a glass you see him torment these unhappy birds unceasingly, until they let fall into the sea a whitish, greenish mass, which he seizes and swallows in an instant. The early witnesses of this performance imagined that this mass was nothing else than the dejection of the sea bird, and therefore concluded that the stercorarius had a singular method of alimentation (whence the name). But in reality that is not the explanation. The mass rejected is a fish only just swallowed by the bird, who is forced by the stercorarius to regurgitate it; to this end the latter follows without rest and strikes his quarry violently on the head until the booty is abandoned to him. If the bird resists, which rarely happens, he strangles it and tears it to pieces.

FLAMINGOES' NESTS.[a]

By Frank M. Chapman.

Not very many years ago, so little did we know about the nesting habits of the flamingo, it was commonly believed that the incubating bird straddled the nest when hatching, letting her legs hang down on either side! The observations of H. H. Johnston[b] and Abel Chapman[b] on the European species (*Phœnicopterus antiquorum*) and of Sir Henry Blake[c] on the American species (*P. ruber*) proved the absurdity of this belief by showing that incubating birds folded their legs under them in the usual way, but we still know very little about the nesting habits of these birds.

Largely with the object of studying the flamingo on its nesting grounds I went to the Bahamas in April of the present year, accompanied by Mr. Louis Agassiz Fuertes, the well-known artist. At Nassau we joined Mr. J. Lewis Bonhote, of Cambridge, England. Mr. Bonhote was formerly governor's secretary in the Bahamas, when he acquired a knowledge of the islands which was of the greatest value to us. He had already made a reconnoissance in search of flamingoes' nesting retreats, and with the aid of one of the few natives who was familiar with their whereabouts had succeeded in reaching a locality on Andros Island, at which the birds had bred the previous year.

It is not my purpose to recount here the various adventures which befell us while cruising about the Bahamas in a very comfortable 50-ton schooner, and I proceed at once to a description of our experiences with the flamingo.

Flamingoes are late breeders. It is not improbable that the time of their nesting is dependent upon the rainy season, which, in the Bahamas, begins about the middle of May. Consequently we deferred our trip to the locality previously visited by Mr. Bonhote until the middle of May. Then we anchored our schooner at the mouth of a certain channel, and, loading our small boats with needed supplies, rowed for the better part of a day, pitching our tents toward evening on a low, slightly shelving shore with a background of dense, scrubby vegetation. Exploration of the surrounding country showed that it was regularly frequented by flamingoes in numbers during the nesting

[a] Reprinted, by permission, from Bird Lore, The Macmillan Company, Harrisburg, Pa., and New York, Vol. IV, 1902, pp. 177–181.

[b] The Ibis, 1881, p. 173; 1883, p. 397.

[c] Nineteenth Century, 1887, p. 886.

season. Within a radius of a mile no less than eight groups of nests were discovered. They showed successive stages of decay, from the old nests, which had almost disappeared before the action of the elements, to those which were in an excellent state of preservation and were doubtless occupied the preceding year. Some were placed among young, others among fully grown, mangroves, and one colony, probably inhabited in 1900, was situated on a sand bar 200 yards from the nearest vegetation. All the colonies found contained at least several hundred nests, and the one on the sand bar, by actual count of a measured section, was composed of 2,000 mud dwellings. What an amazing sight this settlement must have presented when occupied, with the stately males, as is their habit, standing on guard near their sitting mates!

Flamingoes in small flocks containing from 3 or 4 to 50 individuals were seen in the vicinity, but it remained for Mr. Bonhote's negro assistant to discover the spot which had been selected by the birds for a nesting site in 1902. Climbing a small palm, an extended view was had of the surrounding lagoons, sand bars, and bush-grown limestone; and he soon exclaimed, "Oh, Mr. Bonhote, too much, too much filly-mingo!" Less than a mile away, indeed, was a flock estimated to contain at least 700 of these magnificent birds, which Mr. Bonhote approached so cautiously through the thick growth of mangroves, that he was fairly upon them before they took wing. They had not then begun to build, but the open spaces among the mangroves were closely dotted with nests (see illustration), which apparently had been occupied the preceding year and in some of which old eggs were seen. Here, some days later, nests were found in the early stages of their construction; but, to our great regret, circumstances compelled us to leave before they were completed and we did not, therefore, see the birds upon them. However, we learned some things regarding the nesting habits of flamingoes which, in view of our comparative ignorance of the ways of these birds at this season, it may be worth while recording.

In the first place, although the birds return to the same general locality year after year, they apparently use a nest only one season. This seemed proven by the nicely graduated series of groups of nests which we found, each one of which, beginning with those best preserved, seemed about a year older than the other, and by the fact that the birds were building fresh nests near numbers of others which were seemingly as good as new.

The thousands of nests seen were built of mud, which the nests in process of construction showed was scooped up from about their base. In fact it is difficult to conceive of a flamingo carrying mud. In selecting a nesting site, therefore, the bird is governed by the condition of the ground, which, to be serviceable, must be soft and muddy.

NESTS OF FLAMINGOES.

Part of a colony believed to have been occupied in 1900. A view of the entire colony, which contained about 2,000 nests, is shown in Pl. II.

FIG. 1.—COLONY OF ABOUT 2,000 FLAMINGO NESTS.

A section of this colony is shown in Pl. I.

FIG. 2.—FLAMINGO NESTS AMONG MANGROVES.

Believed to have been occupied in 1901.

FIG. 3.—PART OF A FLOCK CONTAINING 37 FLAMINGOES.

Photographed with a 14-inch lens at a distance of about 250 yards. Enlarged 4 diameters.

For this reason, as I have suggested, the time of the breeding season may be regulated by that of the rainy season; the heavy, tropical downpours not only moistening the earth, but doubtless raising the water sufficiently in this exceedingly low, flat country to slightly flood large areas. While the birds, therefore, must build near, or, indeed, in the water, they guard against complete submergence of their home by building it high enough to protect the egg from possible danger. The popular conception of a flamingo's nest makes it not more than 6 or 8 inches in diameter at the base, whence it tapers to a truncate, hollowed top nearly 2 feet in height. I saw no nest, however, over 12 inches high, and most of them were not over 8 inches high. The average basal diameter was about 13 inches, that of the top about 10 inches.

It is possible that the height of flamingoes' nests, like that of the mid-chimneys to the burrows of fiddler crabs, may depend upon the amount of rise and fall in the neighboring waters. This is a point to be ascertained by subsequent observations.

Flamingoes are wonderful birds. Their brilliant coloring and large size, habit of perching and flying in files, and the openness of the country which they inhabit, all combine to make a flock of flamingoes one of the most remarkable sights in bird life. Indeed, so far as my experience goes, it is the most remarkable sight in bird life.

They are very shy and can be approached closely only when they are unaware of your presence. Attempts to use a telephoto lens in photographing birds about 200 yards away failed because of the force of the trade winds over the mangrove flats. Even at this distance the birds are large enough to make a strip of glowing color, in strong contrast to the blue water before and the green mangroves behind them. This is near their danger line, and if one attempts to approach more closely without cover there is a sinuous movement along the whole line as the long, slender necks are raised and the birds regard the cause of their alarm. Soon a murmur of goose-like honkings comes to one's ear; then the birds begin, in slow and stately fashion, to move away step by step, and if their fears are not allayed the leader will soon spring into the air and, followed by other members of the flock, stretch his long neck and legs to the utmost and begin a flight which usually takes them beyond one's view. As the birds raise their wings, displaying the bright feathers below, the effect is superb beyond description, the motion showing their plumage to the best possible advantage.

It is surprising how far, under the proper light conditions, even a small flock of flamingoes may be seen. Long after one can distinguish the individual in the waving, undulating line of birds, they show pink against the sky like a rapidly moving wisp of cloud which finally dissolves in space.

UPON MATERNAL SOLICITUDE IN RHYNCHOTA AND OTHER NONSOCIAL INSECTS.[a]

By G. W. Kirkaldy.

Since my brief note on this subject (Entom. 1902, vol. xxxv, pp. 319–320) I have seen a lengthy paper by the celebrated J. H. Fabre [5][b] on "Pentatomas," in which he ridicules De Geer's account, and consigns the whole recital to the limbo of fairy tales.

I have therefore looked up the literature of the subject, and have now summarized it, in the hope that some of the readers of The Entomologist may be disposed to give the phenomena their attention during the ensuing months.

ORDERS OTHER THAN RHYNCHOTA.

The earliest reference to parental care in nonsocial insects appears to be that of Goedaert [9], who states that the mole crickets (*Gryllotalpa gryllotalpa* Linn.) take particular care of their eggs, raising up the nests in a hot and dry season so that the young almost touch the surface of the earth, and are thereby cherished by the sun's heat; contrariwise they sink the nests down when the air is cold and moist. They also act as unceasing sentinels round the nest. Rösel [22] cites the above account, and gives a colored sectional drawing of the nest and eggs. Audouin [1] states that all authors agree in saying that the mole cricket takes the greatest care of its young, but Goedaert is the only author I can trace who relates his personal observations.

The discovery of the maternal solicitude of the earwig (*Forficula auricularia* Linné) by Frisch [6], confirmed and extended by De Geer [8], Rennie [21], Kirby and Spence [14], Camerano [4], etc., is so well known and authentically established by recent observations, that it is not necessary to dwell upon it. Sharp [23] states that *Labidura riparia* "is said to move its eggs from place to place, so as to keep them in situations favorable for their development," but I have not been able to trace the original source of this statement. Burr [3] also notes that "a certian entomologist [Colonel Bingham] once told me that in

[a] Revised by the author from The Entomologist, vol. xxxvi, May, 1903, pp. 113–120.
[b] These numbers refer to the bibliography at the close of the paper.

Burma, while sitting round the camp fire one night, they disturbed a large earwig who was guarding a little batch of eggs. Her first care was not for herself, but for her eggs. She showed great concern for their safety."

In the Hymenoptera I do not refer to the well-authenticated instances of maternal providence in the Sphegidæ and other families, this notice being confined to actual personal and continuous care. A summary of the former will be found in Sharp [24], page 111. Of the latter there is one instance, viz, *Perga lewisii* Westwood, a Tasmanian sawfly. The habits of this tenthredinid were related [16 and 17] by R. H. Lewis, who informs us that the eggs, in number about 80, are placed transversely in a longitudinal incision between the two surfaces of a leaf of a species of eucalyptus. On this leaf the mother sits till the eggs are hatched. She follows the larvæ, "sitting with outstretched legs over her brood, preserving them from the heat of the sun, and protecting them from the attacks of parasites and other enemies." It should be noted, however, that broods accidentally or purposely deprived of the mother appeared to thrive just as well. These observations have been briefly confirmed by Froggatt [7].

In the Coleoptera, the only instances known to me occur in the Scolytidæ, among the Ambrosia beetles, and a consideration of these scarcely comes within the scope of this notice, since they are not non-social insects. The reader may be referred to Kirby and Spence [14] and Hubbard [25].

Mr. R. South and Mr. L. B. Prout are not aware of any instance among the Lepidoptera, and similar advice has been given me by Mr. G. H. Verrall and Mr. J. E. Collin of the Diptera and by Mr. W. J. Lucas of the Neuroptera. Research on the literature of the Thysanoptera, Anoplura, Thysanura etc., has failed to trace any such records.

I must here also express my thanks to Messrs. W. F. H. Blandford, C. O. Waterhouse, C. J. Gahan, W. F. Kirby, and Drs. G. Breddin and D. Sharp for information and hints.

RHYNCHOTA.

The earliest Rhynchotal notice is that of Modeer [18]. In speaking of "*Cimex ovatus pallide griseus*," he distinctly affirms that the eggs are laid in June on the common birch, in number from 40 to 50, so that the mother can cover them when she sits over them. She does not abandon them except for brief refreshment, and can not be removed except by superior force. The eggs are hatched at the end of June, and the maternal care is still exercised, for she protects them against the male, whose attacks and the defense of the mother are circumstantially related. The great De Geer [8] confirms and expands the observations under the head of *Cimex betulæ* (he gives

C. griseus Linné as a synonym!). Boitard [2], in his Curiosités d'Histoire Naturelle—a work unknown to me—embellishes these accounts, according to Fabre [5], by noting that when it rains the mother leads her young under a leaf or under the fork of a branch to shelter them, and covers them with her wings. Montrouzier [19] observed the habits of Oceanian Scutellerinæ, a subfamily not closely allied to the Acanthosomatinæ (in which the birch bug is included). His remarks have been recently translated in The Entomologist [15]. Montrouzier appears to have been unaware of the researches of Modeer and De Geer. Douglas and Scott [20] quote a letter addressed to the former by E. Parfitt, inclosing an adult female and young ones indentified as *Acanthosoma griseum*. This letter circumstantially verifies De Geer's observations, which, so Parfitt states, were unknown to the English entomologist. These habits were still further confirmed in great detail, in three notices [10, 11, and 12], by Hellins, a well-known and most careful observer.

Last year I contributed to The Entomologist [15] a translation of Montrouzier's observations [19], and noted "a species of *Spudæus* (?)" sent by Doctor Willey from Birara (New Britain), of which I had under my care for study alcoholic specimens apparently confirming the generally accepted opinion. These specimens belong to the Pentatomine *Coctoteris exiguus* Distant, a determination kindly confirmed for me by the author of the specific name.

So far the five original observers—viz, Modeer, De Geer, Montrouzier, Parfitt, and Hellins—agree that the female bug does show parental affection during a comparatively considerable period, and the first named declares that this is, in part at least, directed against the assaults of the male; but in 1901 J. H. Fabre—the "immortal Fabre" of Darwin, and one of the foremost of modern field observers—has published a lengthy document [5], in which he declares De Geer[a] to be mistaken. The gist of Fabre's paper is as follows: The gray bug[b] is rare in Fabre's neighborhood. He found three or four specimens which he placed under a bell jar, but they did not oviposit, though eggs were laid by the green [= *Palomena prasinus* (Linné)], red and black speckled [= *Eurydema ornatus* (Linné)], and yellowish [sp. ?];[c] and Fabre continues: "In species so closely allied, parental care in one ought, at least in some details, to be discovered also in the others." It can not be too strongly expressed that the last three are not at all closely related to the gray bug, for the last named belongs to the

[a] The Swedish master and Boitard are the only authors mentioned by Fabre, and he appears to be unaware of the independent observations of Montrouzier, Parfitt, and Hellins.

[b] *Elasmostethus griseus* (Linné)=*Acanthosoma interstinctum* of Saunders's "Hemiptera Heteroptera of the British Isles."

[c] Fabre calls these all "*Pentatoma*."

Acanthosomatinæ, the other three to the Pentatominæ, subfamilies distinguished apart by considerable and important structural differences. Fabre declares that in these species "the mother paid no attention to her brood; the last egg laid in its place at the extreme end of the final row she left, careless of the trust; she no longer busied herself with it, and returned no more. If the chances of roaming bring her back, she walks over the heap and passes on, indifferent. * * * This forgetfulness must not be considered as a possible aberration due to captivity. In the full freedom of the fields I have discovered divers broods, among which are found, perhaps, that of the gray bug. Never have I seen the mother mounted over her eggs, as she ought to, if her family required protection as soon as hatched. The mother is of roving inclination and facile flight. Once flown far from the leaf which received the treasure, how, two or three weeks later, will she remember that the hour of exclusion approaches? How will she rediscover her eggs, and how again distinguish them from those of another mother? It would be incredible—such prowess of memory amid the immensity of the fields.

"Never, I say, is a mother surprised stationary near the eggs that she has fixed on a leaf, and, more convincing still, the total brood is divided into clutches scattered haphazard, so that the family in its entirety is formed of a number of tribes lodged here, there, and at distances sometimes considerable, but impossible to fix precisely. To rediscover these tribes at time of hatching, earlier or later according to the date of oviposition or the forwardness of the season, and then to reassemble in one flock from the four corners of the universe all the little ones, so feeble and moving so unsteadily—there are in this evident impossibilities. Suppose that by chance one of the groups is discovered and recognized and that the mother devotes herself to them. The others must in that case be abandoned—and they do not prosper the less. What, then, is the motive for this remarkable maternal zeal with regard to the care of one of the groups when the majority are left? Such singularities inspire mistrust.

"De Geer mentions groups of 20. These would certainly not be the complete family, but just a tribe resultant from a partial oviposition. A Pentatoma, smaller than the gray bug, has given me in a single batch more than 100 eggs. A like fecundity ought to be the general rule when the mode of living is the same. Beyond the 20 observed, what became of the others abandoned to themselves?

"Despite the respect due to the Swedish savant, the caresses of the mother bug and the unnatural appetites of the father, devouring his little ones, ought to be relegated to the same limbo as the childish tales which encumber history. I have watched in an aviary (volière) as many hatchings as I wished. The parents were near at hand, under the same roof. What do they all do in the presence of the young?

Nothing at all. The fathers do not dash to drain the juices of their brats. Neither do the mothers rush to protect them. One flits about the latticework (treillis) [? metal gauze], one settles down to refreshment at the rosemary, while another walks over the groups of newly hatched youngsters, which he tumbles head over heels, without any bad intention, but without any discretion. The little beggars are so small, so feeble, that, passing by, he grazes them with the end of his foot and overturns them. Like turned turtles, they vainly kick about; no one heeds them.

"During three months' assiduous observations I have not noted the slightest appearance of the maternal solicitude so celebrated by the compilers. The newly hatched bugs, packed one against the other, remain stationary for several days on the empty eggs; there they acquire a firmer consistency and brighter coloring. Hunger comes: one of the youngsters leaves the group in search of refreshment; the others follow, happy in their mutual proximity, like sheep at pasturage; the first in moving sets in motion the whole band, who set out for tender places where they may implant their beaks and imbibe; then they all return to their natal place for repose upon the empty eggs. Expeditions in common are repeated over an increasing radius, till at last, somewhat strengthened, the society separates and breaks up, never to return to its place of birth. Henceforth each one lives in his own way. What, then, would happen if, when the troop moves away, there should encounter them a mother of slow gait, a frequent case among the sedate bugs? The young ones, I suppose, would confidently follow this chance leader, as they follow those among themselves who are the first to take to the road. There would then be some similarity to a hen at the head of her chickens. This casual occurrence would lend an appearance of maternal cares in a stranger heedless of her bundle of brats.

"The good De Geer appears to me to have been duped in some such manner; a little color, involuntarily embellished, has completed the tableau; and then are vaunted in books the family virtues of the gray bug."

Fabre has been led into error, first, by his ignorance of systematic rhynchotology—as I have previously remarked, the form of bug which De Geer had under observation belongs to a subfamily not closely allied to that embracing the bugs watched by Fabre; secondly, by his negligence of previous literature, except that of De Geer (and incidentally Modeer) and Boitard; yet we have an independent observer, Montrouzier, ignorant, apparently, of all previous similar records, who notes a like habit in yet another subfamily, more remote still from either, and that almost at the antipodes of Europe. Moreover, De Geer's accounts are explicitly corroborated by two competent field entomologists whose integrity and capacity have never before been

questioned, and one of these (Parfitt) was by his own account ignorant of any literature on the subject. So that Fabre's gibe at messieurs the compilers has failed to score. Boitard's account may perhaps be treated a little incredulously, and possibly also Modeer's interpretation of the paternal gymnastics. In my opinion, at least, it will be necessary to have much more direct refutation of De Geer, Hellins, and Parfitt than the observations of even Fabre on species of another subfamily.

With regard to Fabre's asseveration that he never once found a female "Pentatoma" stationary near the eggs, this is circumstantially contradicted by the precise observations of Hellins and Parfitt in Elasmostethus. Neither has the French author proved his theory, upon which he establishes so large a part of his assumptions, that the Pentatomidæ (or at least some of them) oviposit in more than one place. It is to be regretted that he did not examine the oviducts of one of the females observed by him. Moreover, it does not appear that Fabre marked any of the female Pentatominæ observed by him so as to recognize them in the event of any "chance" returns to the original spot. Fabre also says, "A Pentatoma smaller than the gray bug has given me in a single batch more than 100 eggs," and insists therefore that De Geer's record of 20 in the gray bug could have been only a partial laying!

This confines the subject entirely to the Rhynchota; now we have also, as noted above at the beginning of this paper, records of the devotion of the mother earwig (and of more species than one), records as well authenticated as such could well be, not only in written literature, but from living observers who have not considered it worth while to register what has always appeared as a thoroughly firmly founded fact. The occurrence in *Gryllotalpa gryllotalpa* seems also authentic, while the recent confirmation by Froggatt, after seventy years' interval, of Lewis's observations on *Perga lewisii* establishes this remarkable case beyond doubt, and it is especially interesting to note that in other Australian species of the same genus entirely different larval habits are known to obtain; the latter is another argument against Fabre. What is there of incredibility in the whole recital? What a limited demonstration of affection, or at least of intelligent power, compared with that displayed by the social Hymenoptera and Neuroptera! Fabre argues as if parental solicitude and the sense of direction were unknown among the insecta, and his sneer at the inadequacy of the memory of the mother bug to rediscover the original place of oviposition is remarkable enough from the historian of the habits of the Hymenoptera.

To conclude, Fabre may prove to be right, and Goedaert, Frisch, Modeer, De Geer, Kirby and Spence, Rennie, Montrouzier, Boitard, Lewis, Parfitt, Hellins, Camerano, Froggatt, and Bingham, all, to a

man, wrong; but even if so, Fabre has proved nothing at present beyond the fact that the females of two or three species of Pentatominæ, not particularly closely observed by previous authors, did not manifest any regard for their progeny during his observations. It is perhaps not the "good De Geer" who "has been duped," but Fabre, who has been led astray by his ignorance of the systematics and bibliography of the Rhynchota.

ADDENDUM (March 30, 1904). Since the above was published various confirmatory evidences in support of my views have been found. H. Schouteden [26] has noticed my paper at some length and mentions two papers previously unknown to me. He further relates an early observation of his own on the gray bug in Belgium, where he noted a female brooding over its eggs and holding on tightly, without emitting any odor, when seized in the fingers.

Reiber and Puton [27] cite the case of a female of the same "sitting on its freshly emerged young ones on a birch leaf." The Abbé Pierre [28] also cites his experiences of this species, confirming the foregoing accounts.

Miss Murtfeldt [29] describes the devotion of a membracine, *Entylia*[a] *sinuata*, from Central Missouri, feeding chiefly on *Ambrosia* (ragweed). Her observations on this *Homopteron* entirely accord with the previous recitals.

Finally, my friend Mr. E. E. Green writes to me from Peradeniya, Ceylon (May 29, 1903). I take the liberty of quoting his words: "The female of several of the leaf-haunting reduviids—e. g., *Endochus cingalensis* and allied forms remain near their egg clusters until these are hatched. The young are at first gregarious, and the parent may usually be seen on the same leaf, watching over them like a hen with her chicks. It seems possible that she may catch insects to provide them with food, but I have no evidence of this."

With regard to other insects, Barrett [30] writes: "The female of the northern mole cricket (*Gryllotalpa borealis*) is said to care for her young until they reach the second molt." No reference is given.

Rennie [31] states that the eggs and young of the mole cricket (*Gryllotalpa gryllotalpa*) are "exposed to depredation, and particularly to the ravages of a black beetle who burrows in similar localities. The mother insect, accordingly, does not think her nest secure till she has defended it, like a fortified town, with labyrinths, intrenchments, ramparts, and covert ways. In some part of these outworks she stations herself as an advance guard, and when the beetle ventures within her circumvallations she pounces upon him and kills him." The raising of the nests by *Gryllotalpa* is also mentioned by S. S. Rathvon. (Entomology in Rep. Commr. Agr. U. S. for 1862 (pub. 1863), p. 379.)

[a] Unfortunately written *Eutilia* throughout.

Outside Hexapodous Arthropoda, Mr. R. C. L. Perkins informs me that the myriapod *Scolopendrella* (*lucasi?*) may often be seen in the Hawaiian Isles, coiled round its young, protecting them; while Huxley (Introduction to the Study of Zoology, Internat. Sci. Series, XXVIII, pp. 42 and 351–2) discusses the affection of certain crustacea for their young.

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[a] I do not know Montrouzier's forename. Hagen cites it as "P." (Bibl. Ent. i, p. 547), but this is merely an abbreviation for "Père." He is indicated in his papers as "R. P." and "P. A.," possibly "Révérend Père" and "Père Abbé."

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THE PSYCHICAL FACULTIES OF ANTS AND SOME OTHER INSECTS.[a]

By A. Forel.

A fine example of the fact that complicated psychical combinations require a large nerve center having under its control the sensory and motor centers is afforded by the brain of the ant. An ant colony is usually made up of three kinds of individuals—females (the largest), smaller workers, and males, who are rather larger than the workers. The workers have, more than any of the others, complicated instincts, and with them intellectual faculties (memory, plasticity, etc.) are readily demonstrable. The females have much less. The males are incredibly stupid; they do not distinguish friends from foes, and are unable to find their way to the nest. They have, however, well-developed eyes and antennæ; that is to say, the only two sense organs that are connected with the brain or supra-esophageal ganglion, and these enable them to successfully pursue the female in flight. No muscle is innervated from the supra-esophegeal ganglion. This fact makes very much easier the comparison of the organ of thought—i. e., the brain (*Corpora pedunculata*)—in the three sexes. It is very large in the workers, much smaller in the females, almost atrophied in the males, though the olfactory and optic lobes are in the latter quite large. The cerebrum of the ant workers possesses also a cortex extraordinarily rich in cells. Injury to the cerebrum in ants is followed by results similar to those which occur in the pigeon.

Insects appear to possess sight, smell, taste, and touch. Hearing is doubtful. It is possibly replaced by a tactile sense modified for delicate appreciations of concussion. A sixth sense has never been demonstrated. A modified photodermatic sense for perception of light must be considered as a variety of the tactile sense, and occurs among many insects. This is in no way an optical sense. In water insects, smell and taste become somewhat blended (Nagel), for chemical substances dissolved in water are detected by either sense.

[a] Translated and condensed from the Proceedings of the Fifth International Zoological Congress, held at Berlin, August 12–16, 1901, pp. 141–169.

The vision of the retinal eye is especially directed to the detection of movements—i. e., to the relative local changes in the retinal picture. In flight it localizes large space areas, but defines contours of objects less sharply than our eye does. The retinal eye gives but a single upright image (Exner), whose clearness increases with the number of facets and the convexity of the eye. Exner succeeded in photographing this image in *Lampyris*. The immobility of the eyes necessarily makes it impossible for an insect at rest to see stationary objects situated laterally from it. This is the reason why insects at rest are so easily caught by slow movements. In light, insects orient themselves in space by means of the retinal eyes. By the displacement of pigment many insects can adapt their eyes for use by day or by night. Ants perceive the ultra-violet rays with their eyes. Bees and beetles distinguish colors, though indeed not as the same tints that we do, since they are not attracted to those flowers that seem to us most beautiful. Perhaps this comes from some mixture with the ultra-violet rays not perceived by us.

The ocelli play a subordinate part and apparently serve only for near vision in dark places.

The olfactory sense resides in the antennæ, especially in their club-like ends—that is to say, their pore plates and olfactory bulbs. Being movable and externally situated upon the antennal tips, they impart to the insect at least two attributes wanting to vertebrates and especially to man:

(*a*) The ability to recognize the chemical qualities of an object by means of direct contact (tactual smell).

(*b*) The ability to recognize and distinguish, by means of odor, the shape and extent of an object, including also the form of its own track, and in this way to establish associated memories.

The olfactory sense of many insects gives, therefore, definite and clear relations of known space, and may serve very well to orient animals that move about on the ground. I have on that account named this qualitative sense, quite differing from our smell in its specific energy, topochemical olfaction. Apparently the pore plates serve to detect odors at a distance and the olfactory bulbs for tactual smell, yet this is only supposition. The removal of the antennæ destroys the power of distinguishing friend from foe and deprives the ant of the ability to orient itself on the ground or to find its way, while three legs and an antenna may be removed without essentially injuring these functions. The topochemical sense enables the ant to distinguish from each other the two directions of its trail, an ability which Bethe considers to be due to a mysterious polarization.

The organ of taste is found in the mouth parts. The taste reactions of the insect are very similar to our own. Will, having accustomed wasps to seek honey at a definite place, then put quinine in it. The

wasps noticed this immediately, showed symptoms of disgust, and did not return. When he replaced the honey with alum they at first came back, but after experiencing the unpleasant taste ceased to come. It may be said, by the way, that this is also a testimony as to their memory for tastes and their power of association.

Various organs for hearing have been described. The auditory reactions do not change, however, after the removal of such organs, which leads to the supposition that there is a sort of pseudo-audition by means of a perception of delicate vibrations through the tactile organs (Dugès).

The tactile sense has for its organs tactile hairs or tactile papillæ. It reacts especially to delicate vibrations of the air or of the support. Certain articulate animals, especially spiders, orient themselves preferably by means of the tactile sense.

It may be demonstrated that insects are accustomed to combine their various senses for the orientation and recognition of the outer world according to the species and the needs of their life. Eyes and vision are wanting in many species. Others, on the contrary, have a very dull olfactory sense; certain forms lack tactual smell—for example, most of the diptera.

The great power of orientation possessed by some aerial animals, like birds (carrier pigeons), bees, etc., demonstrably depends upon vision and visual memories. It is of enormous value in aerial flight. The semicircular canals of the auditory nerves provide a sense of equilibrium and give sensations of acceleration and turning (Mach-Breuer), but they do not orient the individual as regards the outer world. A specific power of orientation, magnetic or otherwise, independent of the other senses does not exist.

Taking these senses as elements, we have a basis for insect psychology.

Domain of perception.—It may be considered as established that many insects (apparently all in some rudimentary degree) possess memory, i. e., the power of storing up sense impressions in their brains and turning them to account later. Bees, wasps, etc., will find their way back to a concealed place, not visible from their nest, where they had found some substance they liked, even after its removal and when days and weeks have elapsed. They do this, too, by flight through the air, during wind and rain which would remove every trace of odor, and even after excision of their antennæ.

The topochemical sense possessed by the antennæ also gives excellent evidence as to the possession of memory by ants, bees, etc. An ant will make a difficult journey, sometimes as far as 30 meters, from a nest that has been destroyed, and, finding there a place suitable for building a new nest, will return (orienting itself with its antennæ), and seize a companion, which he rolls around himself and carries to

the place he has found. Each of these then retraces the way and both repeat the maneuver with other companions, etc. The recollection that that place is suitable for building a nest must reside in the brain of the ant. The slave-making ants (*Polyergus*) will undertake robber raids, led by a single worker, who, days and weeks before, has discovered the way to the nests of *Formica fusca*. The ants often lose their way, then stop and search for a long time until they again find the topochemical trail, when they give to the others the right direction for their farther journeying by sharply pushing them. The *Polyergus* will take the pupæ of the *Formica fusca* from the depths of the nest and carry them off to put into their own nests (often as far away as 40 meters or more). If the despoiled nest contains still more pupæ the robbers return on the same day or the following day; otherwise they do not return. Only the memory, i. e., the recollection that there were still many pupæ in the despoiled nest can lead to the return thither. I have followed up a great number of such raids.

While the species of *Formica* carefully and painstakingly go back over their topochemical trail, they know the immediate surroundings of their nest so well that even shoveling away the ground does not disturb them, and they find their way immediately. This is not by perceiving the odor from a distance. Certain ants can recognize their friends after the lapse of months. Among ants and bees there are very complicated olfactory combinations and mixtures, which Von Buttel has quite justly distinguished as nest odor, colony (family) odor, and individual odor. Among ants there is also a species odor, while the queen odor does not appear to play such a part as it does among bees.

From these and many other facts we conclude that the social *Hymenoptera* store up in their brains visual and olfactory (topochemical) impressions, and combine them to form perceptions or something similar; that they associate these perceptions, even those of different senses—especially those of sight, smell, and taste—so as to obtain conceptions of space.

These animals, by the frequent repetition of an act of traversing the same way, etc., acquire a rapidity and a celerity in their instinctive performances. Habits are formed by them with great rapidity. Habit, however, implies secondary automatism and previous plastic adaptation. Bees who have never flown away from the hive (although they may be older than many others who have so flown) do not find their way back at all, even if the hive is only a few meters distant, if they can not see it directly, while other bees know the entire neighborhood, often within a range of 6 or 7 kilometers.

From the accordant observations of experts we therefore conclude that among the social insects sensation, perception, association, deduct-

ive power, memory and habit follow in general the same elementary laws as they do in vertebrates and in man.

On the other hand, inherited automatism greatly preponderates with them. The abilities just mentioned are very weak indeed outside the range of instinctive automatism peculiar to the species.

An insect is extraordinarily stupid and unadaptable for everything that does not relate to its instinct. I once taught a *Dytiscus marginalis* (water beetle) to eat upon my table. In doing this he always, by stretching out his fore legs, made an awkward movement which brought him upon his back. He indeed learned to continue to eat while in that position, but not to abstain from this movement. On the other hand he tried to spring out of the water (no longer to flee to the depths of the bucket) as soon as I entered the room, and gnawed quite familiarly at the tip of my extended finger. This was certainly a plastic variation of instinct. In the same way the large Algerian ants which I transferred to Zurich, learned in the summer months how to close up the wide opening of their nest with balls of earth, because they were followed and annoyed by our small *Lasius niger*. In Algiers I always saw the nest openings widely open.

That ants, bees, and wasps communicate to each other information which is understood is so well attested that it is unnecessary to waste a word upon the subject. The observation of a single robber raid of *Polyergus* would suffice to show this. Yet this is not speech in the human sense. There is no corresponding abstract conception attached to these signs. We are dealing with inherited, instinctive, automatized signs (pushing with the head, rushing at each other with open jaws, vibrating the antennæ, disturbing the ground with the body, and many others). Imitation also plays a great part—ants, bees, etc., imitate and follow their companions. It is therefore an entire mistake (in this Wasmann, Von Buttel, and myself are entirely agreed) to think that this insect speech indicates anything like human deliberation and human power of apprehension. It is even somewhat doubtful whether a so-called general notion (for example, the notion "ant," "enemy," "nest," "pupa") can arise in the brain of the ant. The matters about which we are sure are certainly interesting and important enough in themselves. They give us a glimpse of the cerebral life of these animals.

A good example will illustrate what has been said better than all generalities:

Plateau has stated that if one covers dahlia crowns with green leaves the bees still return to them. He first covered his dahlias incompletely (only the outer or ray flowers), afterwards completely, but still scantily, and concluded from the result that bees are attracted by odor and not by sight.

In a dahlia bed much frequented by bees and comprising about 43 crowns of various colors I covered with vine leaves certain of the crowns as follows:

(*a*) First, 17 and afterwards a total of 28 were completely covered by bending the leaves about them and fastening them with pins.

(*b*) In 4 only the yellow heart was covered.

(*c*) In 1 this was reversed, the outer colored rays being covered and the heart left free.

So many bees visited the dahlias that there were often several on the same crown.

Result.—The bees immediately ceased to visit the completely covered crowns. Dahlia *c* was soon revisited like those that had been left uncovered. Bees often flew to the *b* dahlias but immediately left them. A few, however, succeeded in getting under the leaves and reaching the hearts.

As I removed the covering of a red dahlia the bees at once flew back to it. Soon a badly covered dahlia was discovered and revisited by them. Later an exploring bee discovered how to reach a covered dahlia either below or from the side. From that time on these bees, and only these, came back to those covered dahlias.

Yet various bees were apparently searching for the vanished dahlias. About 5.30 p. m. a few had discovered the covered crowns. From this time on they were quickly imitated by the others, and in a short time the covered crowns were freely visited. When a bee discovered my device and the entrance to the covered crown he in his succeeding journeys flew without delay to the lower concealed entrance of the vine leaf. As long as one bee alone had found the entrance he was not regarded by the others, but if there were several (usually 4 or 5 at least) they were followed by the others.

Plateau's experiment therefore was a bad one and led to false conclusions. The incompletely covered dahlias were still seen by the bees. When he completely covered them from above the bees were already aware of his trick and still saw the dahlias from the side. Plateau had not reckoned on the memory and watchfulness of the bees.

On September 13 I made some rude imitations of dahlias by sticking yellow heads of hieracium into petunia flowers and placed these under the dahlias. Neither the petunias nor the hieracium were visited by the bees; yet many bees and bumble bees flew at first to my artifacts, quite as many as to the dahlias. They left them immediately, however, apparently noting the error by the smell. The same occurred with a dahlia whose heart had been replaced by the heart of a hieracium.

As a counter experiment I placed a fine fragrant dahlia heart among the white and yellow chrysanthemums neglected by the bees and situated at the border of the dahlia bed. For half an hour all the bees

flew over this heart without noticing it; then there came a single bee which chanced to be followed by a second. From this time on this dahlia heart, situated in the line of flight, was visited like the others, while on the other hand the petunia-hieracium artifacts were no longer regarded because they were now recognized as fraudulent.

Plateau showed that artificial flowers, although they might be very good imitations (for us), were disregarded. I placed such flowers among the dahlias. They were in fact completely unnoticed. Perhaps, as I have already pointed out, the bees could distinguish the chlorophyll colors from our artificial colors by a mixture of ultra-violet rays or in some similar way. As, however, Plateau imagines that the artificial flowers repel the insects, I made on September 19 the following coarsely cut paper flowers:

α, a red flower.

β, a white flower.

γ, a blue flower.

δ, a blue flower with a yellow heart made out of a yellow leaf.

ε, a rose-colored piece of paper with a dry dahlia heart.

ζ, a green dahlia leaf (unaltered).

It was 9 a. m. I placed a drop of honey on each of the artifacts set under the dahlias. For a quarter of an hour numerous bees flew quite near to my artifacts without noticing the honey, therefore without smelling it. I went away for an hour. When I returned the artifact δ had no honey, therefore had apparently been discovered by a bee; all the others were completely intact and had remained disregarded.

I now took pains to place α quite near a bee that was sitting upon a dahlia. The attention of the bee was, however, so engrossed by the dahlias that I had to repeat the attempt four or five times before I succeeded in bringing the honey directly to his proboscis. This one now immediately began to suck the honey from the paper flower. I marked him on the back with a blue color in order to recognize him, and repeated the experiment with β and ε, whose bees I marked with yellow and white. The blue bee flew away, but soon after returned from the hive and went directly to α, at first hovering uncertainly here and there, then to δ, where it fed, then back again to α, but not at all to the dahlias. Later the yellow bee returned to β and fed, then flew to α and δ, where it also fed, and did not trouble itself about the dahlias any more than the blue one had.

Now came the white bee, looked for ε, did not find it immediately, and fed in some dahlias. Yet he tarried in each dahlia but a moment, as if the impelling idea of the honey was vexing him. He came back to the artifacts, whose appearance he seemed not yet to fully associate with the remembrance of the honey, but finally found a separated and somewhat depressed portion of ε and sucked honey in it.

From that time on the three marked bees, and those alone, regularly returned to the artifacts only, paying no further attention to the dahlias. It is a very important fact that those marked bees, entirely of their own accord, doubtless because of an instinctive analogical conclusion, discovered the other artifacts as soon as they became mindful of the honey that one of the same contained, and, indeed, in spite of the fact that the artifact was somewhat distant from the others and was differently colored. The dahlias which they previously visited were also of different colors. In this way the blue bee flew to α, β, γ, and δ; the yellow one to β, α, δ, and γ; the white one to ε, α, β, and δ. For half an hour this went on. The concealed green ζ was not found, apparently because it was not distinguished from the green foliage.

At last a bee, who had apparently noticed the other three, came of his own accord to δ and fed. I colored him carmine. He then flew to α and drove away the blue bee. Another bee was conducted to ε and colored with cinnabar. Still another bee came of its own accord to β and was colored green. It was 12.20 p. m.; the experiment had therefore lasted over three hours, and only 6 bees knew the artifacts, while the great multitude yet resorted to the dahlias. Now, however, the other bees began to notice the ones that visited the artifacts. One, then two, then three and more new ones followed and colors failed me for marking them. Every moment I had to renew the honey. Then I went to dinner, returning at 1.25 p. m. At that moment there were 7 bees in β, 2 in α, 1 in γ, 3 in δ, the white one alone in ε; more than half of them new, unmarked followers. From now on a perfect swarm of bees assailed the artifacts and sucked up the last trace of honey. Now, at last, one bee out of the swarm discovered the artifact ζ, which had, although full of honey, remained thus far unnoticed on account of its color.

Like a pack of hounds attacking a bare skeleton, the swarm of bees, quite diverted from the dahlias, threw themselves upon the artifacts, now totally destitute of honey, and searched every corner of them in vain for honey. At 1.55 p. m. the bees began to disperse and return to the dahlias. I replaced α and β, respectively, with pieces of white and red paper that not a trace of honey had touched, consequently devoid of its odor. In spite of this, these pieces of paper were visited and searched by many bees, their brain yet occupied with the impelling idea of the taste of honey. The white bee, for example, searched the white paper in the most careful manner for three or four minutes. There can here be no question of an unknown force or of an attraction by means of smell or by the beauty of the flowers. These facts can only be explained by recollections of space, form, and color associated with recollections of taste.

I took all the artifacts away, carrying them in my left hand. Two or three bees followed me, flying about my left hand and seeking to settle upon the empty artifacts. The space picture was changed, so the color and form of the object alone suffices bees for recollection.

At 2.20 p. m. all of my bees, even the colored ones, had returned to the dahlias.

On the 27th of September—that is to say, eight days later—I wished to make the same bees distinguish, by color alone, slips of various colors placed in different places on a long, graduaded scale of shades painted on a large sheet of paper and passing from white through gray to black. I wished first to train one bee as to one color. I had, however, reckoned without considering the memory of the bees, which spoiled the whole thing for me. Hardly had I laid my paper and my slips on the meadow near the dahlia bed, set one or two bees upon blue slips and painted them, when they began to fly about to all the red, blue, white, black, and other slips, whether provided with honey or not, and to thoroughly search them. After a few moments other bees came from the dahlia bed, and in a short time a whole swarm descended upon the paper slips. Naturally the slips that had honey upon them were more frequented, because the bees remained there, but those that were entirely free from honey were stormed and searched by groups of bees following one after another in flight, and then again abandoned. The bees even stormed the color box, among them one whose antennæ I had cut off. He had already taken honey from blue slips and had flown back from the hive. He sought the blue cake of color in the color box.

In short, my experiment failed because all the bees still had in their heads the former particolored artifacts associated with honey, and therefore investigated all slips of paper similarly colored. The association "taste of honey and paper slip" was again awakened by the perception of the latter and obtained a standing, as well as rapid, powerful imitation, because honey was really found upon certain of the slips. Ability to perceive and associate implies ability to deduce analogically from individual experiences simple, instructive conclusions, without which the work of perception and memory would be nugatory. We have just given an example of this. I have related in a previous paper that humblebees whose nest I had transferred to my window often mistook for that other windows in the same façade and examined them carefully for a long time before they righted themselves. Lubbock relates similar instances. Von Buttel shows that bees who have become accustomed to a room and a window learned from that to look for a room and a window in other places (other houses). When Pissot covered over the entrance to a wasp's nest with a net whose meshes measured 22 millimeters, the wasps, checked at first, went below around the bottom, etc. Soon, however,

they learned to fly directly through the meshes. The sense of vision in flight is peculiarly adapted to this kind of experiments, which, however, can not be made with ants. Yet the latter doubtless arrive at similar conclusions by means of the topochemical sense residing in their antennæ. The finding of booty or other nourishment upon a plant or near any object leads them to search similar plants or objects, etc.

There are, on the other hand, very stupid insects, such as male ants, diptera, and day flies, with scanty brains, who are unable to learn anything, unable to combine sense perceptions so as to produce anything higher than merely automatic acts, in whom a retention of memory impressions is hardly demonstrable. These respond hardly at all to anything but sense stimuli, but their life is adapted to extremely simple relations. It is here that the difference is best seen, and this demonstrates in the clearest manner, by comparison and contrast, the greater intelligence that the more gifted insects possess.

Domain of the will.—The conception of the will as opposed to that of the reflexes presupposes, between the sense impression and the movement conditioned by it, a certain time as well as an intervening and complicated cerebral process. During the performance of instinctive, purposeful automatisms, which disengage themselves in a certain succession, there is also, as in the will, an interval of time occupied by the interior dynamic processes of the brain. There are, therefore, no pure reflexes. They may be for some time broken off and then again resumed. Yet their execution involves for the most part a linking together of complicated reflexes, which are obliged to follow each other in a definite order and not otherwise. Therefore the expression automatism or instinct is justified.

In order to be able to predicate will in the narrow sense we must establish individual resolves which can be directed according to circumstances—i. e., can be modified—which have the faculty of lying for a certain time in the brain, then to be again brought forward. This will is usually far below the complex human will, which consists of enormously complicated components long prepared and combined. Ants show both positive and negative will phenomena, which should not be confounded. In this the species of *Formica* L. excels, as it especially illustrates in the clearest manner individual psychical activities. In the changes of nest mentioned above we may very well recognize the individual plans of a worker adhered to with the greatest tenacity. An ant will work for hours at some difficult matter in order to attain an end it has proposed for itself. This end is not exactly prescribed instinctively, as many possibilities may be involved, and therefore it often occurs that two ants work against each other. To the superficial observer this may appear stupid. Yet it is provided for in the plastic quality of the intelligence of ants. For some time

the two animals will destroy each other's work. At last, however, they notice this and one gives way and retires or helps the other.

Nest and road making give the best opportunities to observe this—for example, among the wood ants (*Formica rufa*) and, still better, among *Formica pratensis*. To fully elucidate this it is necessary to follow them up for hours at a time.

We may also recognize in the wars of ants very definite purposes of action, especially in what I have called "combats à froid" (chronic fights). After two opposing parties (two colonies that have been brought together) have concluded a peace, single ants are often seen to follow up and maltreat certain individuals of the opposite party. They often carry them far away in order to separate them from the nest. If these excluded ants return and are found by their pursuers, they are again packed off and carried still farther. In one such case it happened that the persecutor brought his victim to the edge of my table. He then stretched out his head and let his enemy fall to the ground. It was not accident, for he repeated the act twice afterwards when I had brought his victim back upon the table. From the various individuals of his former enemies but present allies he had concentrated his antipathy upon this one, and sought to make it impossible for him to return. One must have strong prepossessions to say that in such and many similar cases ants do not form and execute resolves. It is true that these acts are confined to the paths along which the instincts of the species work and that the various steps in the execution of a resolve are performed instinctively. Further, I especially protest against ascribing to the will of the ant human considerations and abstract conceptions. Nevertheless, we must candidly confess that, reversing the positions, we men when executing our resolves constantly allow the intervention of inherited as well as secondary automatisms. While I am writing this my eyes are working with automatisms that are partly inherited and my hand with secondary automatisms. It is of course understood that the complication of my innervations and the accompanying abstract deliberations are such as are peculiar to the human brain.

It may be said in passing that we can explain in a similar manner the relative independence of the spinal cord and the subordinate cerebral centers with reference to the cerebrum in the lower vertebrates (also in lower mammals) as compared with the close interdependence which those organs and their functions have in the mighty brain of man and to some extent in that of apes. The latter separate and control their automatisms (divide et impera).

While success visibly increases both the audacity of the ant and the pertinacity of its will, continued failure or sudden surprise by powerful enemies may occasion an inhibitive despondency leading to the neglect of the most important instincts, to cowardly flight, the eating

or casting out of its own brood, the neglecting of work, etc. There may be a chronic increasing despondency in degenerate colonies and acute despondency occasioned by a lost battle. In the last case one may see a troop of large, strong ants fleeing, without any attempt at defense, before a single small and weak enemy who is following them up. Half an hour before these fugitives would have killed the enemy by a few bites. It is remarkable how quickly the victors note this disposition and avail themselves of it. Discouraged ants are accustomed to collect after flight and soon regain their will and courage. Still they offer but feeble resistance to a renewed attack of the same enemy if it is made, for example, on the following day. Even an ant's brain does not quickly forget a defeat.

In embittered conflicts between two approximately equal colonies the obstinacy of the struggle increases and with it the will to conquer, until one colony or the other is completely overcome. In the domain of the will imitation plays a great part. Arrogance and despondency are also uncommonly contagious among ants.

Domain of the emotions.—Most of the emotions of insects are closely bound up with instincts. This is the case with the jealousy of the queen bee who kills her rivals, and the anxiety of the latter who are yet in their cells; also with the rage of fighting ants, wasps, or bees, with the just-mentioned despondency of ants, the love for the brood, with the self-sacrifice of the working bees, who let themselves die of hunger in order to feed their queen, and with many more. There are also individual affections not necessarily conditioned by instinct, such as the desire of some ants to maltreat certain opponents, as we have stated. As the reverse of this, friendly services (feeding) may, as I have witnessed, be exceptionally offered to an enemy, a mutual feeling of sympathy and finally alliance may take place even between ants of different species. Also with ants sympathy, antipathy, and anger are heightened by repetition and by the acts corresponding to them, as is the case with other animals and with man.

The feeling of social duty is instinctive among ants, and it varies very much according to individuals, times, and occasions, which argues a certain plasticity.

Psychical correlations.—I have hastily outlined the three chief domains of the psychology of ants. It is, of course, understood that here, as elsewhere, there is no sharp division between them. The will consists of the central resultants of the sense perceptions and the emotions, but reacts powerfully upon both of them.

As long as bees are collected on only one species of flowers they overlook all other species and even other flowers of the same species. If their attention is directed to honey that they had previously overlooked, then they have eyes for that alone. An intensive emotion, like swarming among bees (Von Buttel) makes these insects forget all

enmities and even their old parent hive, so that they return to it no more. If, however, the hive was painted blue and the swarm is broken up by taking away the queen, the bees remember the blue color of their old hive and fly to hives that have been painted blue. In a swarm of restless, angrily buzzing bees who have lost their queen two emotions often conflict—that of enmity to strange bees and that of a need for a new queen. If a strange queen is now artificially introduced, they will maltreat or kill her, because the former emotion at first prevails. The bee keepers therefore give them a strange queen confined in a cage of wire gauze. The stranger odor then excites them less because it is more distant, and they can not maltreat the queen. Thereupon they soon recognize the specific queen odor and can feed the strange queen through the meshes of the wire with their trunks. This suffices to immediately quiet the hive. Therefore the second emotion quickly prevails, the workers soon become accustomed to the stranger odor, and after three or four days the queen can be freed without danger.

Among ants the love for dainties may be made to conflict with the sense of duty by allowing a colony of invading enemies to attack and then strewing honey in the path of the defenders that come streaming out. I did this with *Formica pratensis.* At first the ants tasted the honey quite a little, but only for a moment. The sense of duty conquered and all, without exception, hastened to the battle, for the most part to death. Here the higher resolve or instinct prevailed over a lower inclination.

I must to-day again maintain a thesis which I first advanced in 1877 at the time of my installation as privat-docent in the Munich school for higher instruction:

> All the peculiarities of the human soul can be derived from the peculiarities of the souls of the higher animals.

I will now add to this the following: "And all the peculiarities of the souls of higher animals can be derived from those of lower animals." In other words, the doctrine of evolution is just as applicable in the psychical field as in the other fields of organic life. Throughout all the variety of animal forms and their conditions of existence the psychical functions of the nerve elements yet appear in all cases to obey certain elementary laws, even where the differences are so great that this would be least expected.

MUSK OXEN IN CAPTIVITY.[a]

By Jul. Schiött,
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The musk ox is undoubtedly one of the most interesting of the ruminants. Intermediate in form between the sheep and the ox, he is able, even better than the reindeer, to withstand high degrees of cold and to exist upon the scanty resources of the polar regions. In doing this he scorns lichens, the chief winter sustenance of the reindeer, and which were formerly erroneously considered as his principal food. It has been settled, especially through the investigations of Professor Nathorst, that the musk oxen of the arctic fields live upon grasses and other plants which to some extent keep fresh and green throughout the long polar winter, so that the animals have merely to paw away the snow in order to get fodder. During the winter they are also nourished by the reserve of fat accumulated during the summer, when in protected valleys the fruitful earth spreads out a rich carpet of grass.

The hairy coat of the musk ox is warmer than that of any other mammal. Under the long, dark-brown outer hair there grows during the autumn a thick coat of fine, soft wool, which remains until the next summer, when it falls off in large flocks, the long, smooth outer hair remaining. Formerly the musk ox lived in all the countries lying about the north pole and was found much farther south than at present. Its fossil remains have been found in Siberia and England, as well as in Denmark, and even in Germany, about to the limit to which the ice of the glacial period extended. Yet it certainly was never abundant in our hemisphere, and, at any rate, it has not survived the glacial period, as has the reindeer, which extended farther north.

At the present time it is found only in the most northerly regions of the Western Hemisphere, both upon the continent and upon large circumpolar islands, especially in the northern and northeastern portions of Greenland.

Since the time when the great Hudson's Bay Fur Company was founded (1670) the skin of the musk ox has been known in Europe,

[a] Translated from Der Zoologische Garten (Frankfurt A. M.), 1903, pp. 305-317.

and its flesh is very much esteemed by the fur traders, Indians, and Eskimos. The English naturalist, Pennant, published a very correct description and picture of the animal in his work Arctic Zoology (1784–1787), but there had previously been published quite a good picture in a German illustrated work, Die Säugethiere in Abbildungen nach der Natur, Erlangen, 1778. The short, stubbed build of the animal, its white legs, thickly covered with hair, its square rump, the light spot on the back, its whitish muzzle covered with hair, as well as the strong horns characteristic of the male, and which in adult animals reach down toward the ground, are there conspicuously shown. The curvature of the horns is, however, not quite accurate. Certainly the model for the drawing was only a stuffed one; yet naturalists had the opportunity of observing the living animal in its native home, first in the numerous polar expeditions which had for their aim the discovery of the "Northwest Passage," and then in those which

Fig. 1.—Sketch of a musk ox in the year 1778.

were sent out later to map the lands about the north pole and to reach the pole if possible.

The first polar expeditions that went through Baffins Bay found both sides of Smiths Sound—that separates Grinnell Land from north Greenland—inhabited by musk oxen.

When Peary reached, with sledges, the north coast of Greenland and proved that it was a large island he likewise found musk oxen there. In the year 1869–70 the German expedition under Koldewey found them in east Greenland, although not farther south than 73° north latitude, and in greater numbers northward as far as 77°.

Later, in the year 1892, the Ryders expedition met with them in Scoresbys Sound at about 71°, and farther south than that they have not been seen.[a] Professor Nathorst notes, however, that neither

[a] Note by Translator.—The writer doubtless refers here to their southern range in Greenland. On the continent they range as far south as 60°.

Scoresby, who visited this fiord in 1822, nor Clavering and Sabine, who were in that region in 1823, saw any musk oxen. Nathorst shows that these animals must have migrated quite slowly from the northwest side over Smiths Sound into Greenland, and then along the north and east coasts until they finally reached the deeply cut inlet of Scoresbys Sound.

It was also noted that they were followed by polar wolves that took from them many of their small calves. This is the most natural explanation of the fact that so few calves are seen with the herds observed. "In August, 1900," says the zoologist, Sören Jensen, "the Amdrup expedition saw in the regions north of Scoresbys Sound about 400 musk oxen, of which only 13 were calves." When we take into account the slaughter effected by the hunters who land when the ice permits it can be easily understood that the species is in danger of extermination.

It was not until the year 1899 that anyone succeeded in capturing a musk ox and bringing it alive into civilized countries. Even upon the continent of North America this was very difficult, because it was usually necessary to transport the animals upon sledges over long and trackless land journeys. Adult animals could hardly be utilized, firstly, because of their untamable disposition and also because it was with great difficulty that they could become accustomed to new kinds of food. It therefore became necessary to look for calves.

Finally, in the autumn of 1899, a Norwegian arctic hunter brought to Tromsö two calves, which he had captured at Clavering Island, on the east coast of Greenland. They were born in May of the same year, and while on the way he fed them partly on the arctic willows and grasses collected on the spot where they were taken, but chiefly on ship's biscuit. He knew very well the value of his captives and asked for the two calves 22,000 marks. He had, however, to be contented with 10,000 marks, which were paid him by the wealthy Duke of Bedford who has a large zoological garden at Woburn, in the south of England. One of the animals, however, was somewhat weakened and died soon thereafter; the other, a male, died a short time ago, in July of this year. It was very wild and on that account was kept in a strong inclosure where it could not easily be seen.

This profitable capture led all the Norwegian seal hunters to think of giving up the capture of whales and seals and devoting themselves wholly to that of musk calves. At any rate, some of these hunters undertook such captures during the summer of 1900.

The Swedish expedition under Kolthoff, which was sent out to make zoological researches in the arctic regions, now undertook to get musk calves for acclimatization in northern Sweden. Also the Danish expedition to eastern Greenland, under Amdrup, undertook, among

other things, to capture musk oxen, and empowered the author, as director of the zoological garden, to send with it assistants for this purpose.

The summer was a very favorable one, as the ice rarely prevented the vessel from approaching the coast. As a result of all the efforts there was a total of 13 calves obtained. The Danes got a male calf, captured on the 12th of August and which arrived at the zoological garden at Copenhagen on the 7th of October. Here it is still living, and the photographs reproduced herewith show the progress of its development. The Swedes obtained two calves, a male and a female, which were put in a large inclosure in Norrland, where they thrive excellently. The Norwegians relied upon expert hunters, so that they obtained no less than 9 calves, together with 1 male of 1899. It is not quite clear how they made this capture. The Danes, I am sorry to say, used the violent method of shooting down the whole herd of adult animals in order to obtain a calf or calves. It is stated that some of the Norwegians used a better method—namely, that of killing only the mother. Then when the calf took flight with the herd they did not follow it, but secreted themselves near the dead cow. If the calf came back later to the body, they then captured it without much difficulty.

The male of 1899 mentioned above was brought to Hammerfest. Unfortunately during the struggle that occurred at its capture it lost its left horn. It was sold to Carl Hagenbeck and by him disposed of to the Berlin garden, where it is still to be found. Its left horn has grown again, but the tip is wanting.

Two brothers from Aalesund brought in no less than 5 calves, which they sent to the Antwerp garden. These, however, were so weak or so badly nourished that they died, either on the way or shortly after arrival. The remaining 4 arrived in Tromsö. Informed of the matter by Professor Nathorst, C. F. Liljevalch, a wealthy Swede, purchased them and brought them to Medstugan, in Jemtland, in order to attempt to acclimatize them, as Nathorst thought that, on account of their fine wool, they would make valuable domestic animals. Unfortunately one of these had a wound on its back which, being under its thick coat, was not observed. It inflamed, and the animal died. The 3 last (1 bull and 2 heifers) throve very well until the bull and one heifer succumbed on August 30 of last year to a contagious skin disease which carried off a large number of domestic cattle in that region, both last year and the present one. The remaining cow is believed to have been taken to Norrland and placed with the 2 from the Kolthoff expedition.

There are, therefore, at the present time (summer of 1903) living in Europe 5 musk oxen—3 in Sweden, 1 in Berlin, and 1 in Copenha-

FIG. 2.—MUSK OX IN COPENHAGEN, ONE-HALF YEAR OLD, DECEMBER, 1900.

FIG. 3.—MUSK OX IN COPENHAGEN, 1 YEAR OLD, MAY, 1901.

FIG. 4.—MUSK OX IN COPENHAGEN, 15 MONTHS OLD, AUGUST, 1901.

FIG. 5.—MUSK OX IN COPENHAGEN, ABOUT 20 MONTHS OLD, FEBRUARY, 1902.

FIG. 6.—MUSK OX IN COPENHAGEN, 2 YEARS OLD, MAY, 1902.

gen.[a] Unfortunately the two last are both males; it is, however, not impossible that the attempt may succeed that is being made at Copenhagen to cross the musk ox with the somewhat nearly allied yak of Tibet. With his usual kindness and interest in scientific matters Carl Hagenbeck has placed at our disposal two small, hornless yak cows.

Our readers will find herewith a reproduction of a photograph of the smaller of these cows, which is hardly as large as the musk ox. Near by stands a white calf, which was 14 days old and was born from another white and somewhat larger cow. Lydekker (Royal Natural History, vol. II, p. 188) says that this hornless, dwarf race has arisen by crossing with the ordinary Indian cattle (dwarf zebu?). Yet nothing in the structure of this animal indicates a hybrid. Hornless, dwarf races of domestic cattle are indeed quite common. At the same time there will be placed with the musk ox a giant Frisian sheep, and then we shall see to which species he gives the preference. As regards the musk ox himself our pictures will sufficiently show how excellently he has developed. The first autumn (1900) was very rainy and therefore very unfavorable for him. He was uncomfortable and damp in his inclosure and could not move about sufficiently. As rheumatism began to affect his legs, he was removed to another pen, made to move about daily, and later walked about freely in the snow-covered garden every day.[b]

As in the spring of 1901 his horns began to grow and his disposition became less friendly, he was placed in a spacious inclosure situated on a northerly slope. There an open veranda was built to his stall, and with this he was obliged to content himself in rainy weather. As all gregarious animals need society he was provided with companions. After unsuccessful attempts with Shetland ponies and a buffalo calf, he was given a chamois and an old goat. To the latter he soon showed a great liking, a sentiment that has continued since that time. The chamois likewise made court to the goat, and this rivalry, together with daily squabbles at the feeding trough, made the musk ox and the chamois sworn enemies. This enmity has grown greater and greater and has had the most favorable effect upon the welfare of the musk ox. In order to follow and fight his quick-footed enemy he has to run, and thereby gets the necessary daily exercise. The chamois as a rule attacks, like a robber, from behind. In this way he succeeded in the autumn of 1901 in butting his enemy, inflicting a bloody wound upon his hind leg. As a punishment both of the horns of the chamois were tipped with sheaths, which, however, have now become unneces-

[a] Besides these there were brought into Tromsö, since the 26th of August, 1903, by a Norwegian hunter, 5 more calves of 1903—1 male and 4 females—which are at present (September 23) thriving well, but are held at a high price. See also the postscript at the end of this article.

[b] See Der Zoologische Garten, 1901, p. 166 et seq.

sary, as in the spring of 1903 the chamois attacked his companion so boldly and vigorously that he broke off the tips of both horns, and yet he is just as warlike as ever.

Originally the ground within the inclosure was partly overgrown with grass and partly covered with gravel. The hoofs of the musk ox were not sufficiently worn upon this soft ground, and they had to be cut and trimmed. The last cutting took place on September 24, 1901, when the animal was about sixteen months old. Each time he had to be bound and thrown down, and as the projecting horns might be injured and such violent measures also made the animal yet more untamable, quite sharp stones were spread upon the surface of the inclosure in order to make it similar to that of east Greenland. This was apparently a good method, for, since then, the hoofs have been worn off sufficiently and in a natural manner by daily moving about upon the hard ground. Our pictures (pl. IV, figs. 1, 2) show the last cutting, September 24, 1901. In the first picture the musk ox is seen with a noose about his nose and his legs tied together. A keeper holds his head down by grasping his right horn. To the left stands Professor Sand, of the veterinary school, with a knife in his hand. In fig. 2 the professor is seen bending over the animal while busy cutting the hoofs.

The food of the musk ox consists of ground oats and wheat bran, with a very little white bread cut in pieces, besides hay (grass in summer) and willow and elm branches throughout the year. He eats not only the leaves, but is especially fond of the bark, which he strips from even quite small branches, less than a centimeter in diameter. Tannic acid is as necessary for the digestion of the musk ox as it is for the moose. His droppings are globular, like those of deer, goats, and sheep.

The quantity of food taken can not be determined because the chamois and the goat are fed together with him. Yet he takes care to preserve for himself his favorite parts—that is to say, the branches. The musk ox does not drink much and is in the habit of putting his feet into the drinking water; possibly inherited from a habit of cooling the feet in melting snow water.

On the other side of the Atlantic Ocean the famous arctic explorer Greely captured 4 musk calves as long ago as 1881–1884, at Lady Franklin Bay north of Great Bear Sea. It was, however, impossible for him to provide food for them and take them with him.

In March, 1898, Mr. C. J. Jones fitted out a small expedition to the barren lands, a portion of arctic North America, for the purpose of capturing musk calves. He succeeded in taking 5 of them, which he and his white companions drove southward. For two days and two nights they were obstinately pursued by arctic wolves, who wished to snatch their booty from them. When at last they got rid of the

FIG. 7.—MUSK OX IN COPENHAGEN, 3 YEARS OLD, JUNE, 1903.

FIG. 8.—YAK COW AND CALF.

FIG. 9.—PREPARING TO CUT HOOFS OF MUSK OX IN COPENHAGEN, SEPTEMBER 24, 1901.

FIG. 10.—SURGEON PERFORMING THE OPERATION.

FIG. 11.—TWO-YEAR-OLD MUSK OX, NEW YORK ZOOLOGICAL GARDENS, AUGUST, 1902.

wolves they fell asleep, exhausted, and when they awoke they found that some Indians had killed all their calves, having the superstitious fear that all the musk oxen would leave the country, following after their stolen comrades.

These two fruitless attempts had considerably diminished the interest taken by the Yankees in these animals when it was again excited by the news of the fortunate capture made by the Norwegians.

During the winter of 1900–1, an American whaler, Capt. H. H. Bodfish, was forced to pass the winter on the North American coast of the Arctic Ocean. In March, 1901, he sent ashore a part of his force, accompanied by Eskimo hunters. At a distance of 30 English miles from the coast they encountered a herd of musk oxen with 4 calves. They succeeded in capturing all 4, but unfortunately 2 of them were almost immediately killed by the sledge dogs. The two surviving ones were tied fast upon two sledges, taken to the coast and got safely on board ship. The dogs succeeded, however, in killing still another and only the last one, a heifer calf, survived. It was fed with ship's biscuit, willow twigs, and grass collected on the coast, and at last it was safely brought to San Francisco. The owner asked $3,000 for it (about 11,000 kroner or 12,000 marks), but found no purchaser at that high price. Concerning this matter so many telegrams were exchanged that the shares of the Western Union Telegraph Company straightway rose in value! Finally a wealthy man purchased the calf and presented it to the New York Zoological Park. On March 12, 1902, one year after it was taken, it arrived there. A short time after it was photographed, and our picture shows how it appeared when about 2 years old. Its horns then measured 10 inches (24 centimeters) taken along the curvature.

It is remarkable that this cow, taken from the western part of the continent, has itself a light spot upon its forehead, the specific character that Lydekker has assigned to the so-called *Ovibos wardi*, and that is especially thought to distinguish the musk oxen of east Greenland from those of the continent, which are not usually so marked. This specific character does not, therefore, appear to be constant. It has long been known that the size and character of the light spots on the foreheads and backs of individuals of the same region and the same age are subject to much variation. This has already been placed beyond doubt by the experienced Danish zoologist, Herluf Winge, in his excellent work on the mammals of Greenland. In connection with this there may also be mentioned Dr. J. A. Allen's article in the Bulletin of the American Museum of Natural History.

I am sorry to say that the New York Zoological Park did not long enjoy this rare animal. In August he was taken with an inflammation

of the lungs, and, after an illness of a week, died in spite of all the efforts of the veterinary surgeons.

A month later Peary brought to the park a small calf which he had captured in northeast Greenland. It died three weeks afterwards because of an abscess on the back, which had doubtless arisen from a small wound unobserved under the thick fur. We have here a case similar to that of one of the calves brought to Jemtland in 1900.

But our antipodes on the other side of the Atlantic Ocean may console themselves with the reflection that they possess the only musk oxen that are at present living in a wild state upon the globe. We rightly say at present, for how long will this self-supporting animal be able to prolong its life and propagate its race, even in the desolate and inhospitable regions to which it has been driven? How long, indeed? The insatiable enemies of the musk ox, the arctic wolf and man—the most ravening wolf of all creation—follow on his tracks and incessantly thin his ranks. Unfortunately, the ice does not always protect the east coast of Greenland against the landing of hunters as well as it did in 1901 and 1902.

We hope that the attempts at acclimatization which are now being made in Sweden, at the instance of Professor Nathorst, will be crowned with success. That excellent naturalist and unwearied arctic explorer conceived the idea that the musk ox might be domesticated and his extraordinarily fine wool utilized. The impetuous temper of the animal will, however, probably make such an undertaking very onerous; at any rate, much patience and the work of several generations will be required for its success.

Postscript.—Professor Nathorst states, April 7, 1904, that of the pair caught by Kolthoff the cow died in the autumn of 1903 of a liver complaint (intestinal worms), upon which the bull was taken to Jemtland to be bred with the cow left there. Together with this decrease of the number of musk oxen in Europe we can report an augmentation, as the Norwegians have been successful again. Capt. Johan Thjeldson, of the steamer *Laura*, belonging to Magnus K. Gicever, brought home to Tromsö at the end of August, 1903, 5 live musk calves. These were all caught in east Greenland. The first one was caught in the Musk Ox Bay, where Kolthoff in 1900 had found a number of oxen, and where now they met with only half a score. At Cape Graah they came across a flock with 3 calves. Having destroyed the adult animals, they caught the calves in nets. One of them, however, had been grazed in the belly and died a few days after. At Mackenzie Bay they caught 2 more calves. These 5 animals (1 bull and 4 heifers) were placed in a paddock at Tromsö. One of them was smaller than the others and rather delicate. She died in November, whereas the others were getting on well. Unfortunately, one of the heifers strangled itself later on in an attempt to get out of the paddock. The young

bull's legs are said to be bad, possibly from rheumatism, owing to the moist climate. The musk ox in Copenhagen also suffered from that the first autumn. He is getting on splendidly, but has not shown the slightest sign of interest in any of the females (yak cow and Frisian sheep) proffered him.

One of the surviving heifers from Tromsö is now (July 15, 1904) in the garden at Copenhagen, having been secured at a cost of 3,000 kroner, so that at present the garden has the unique distinction of possessing a pair of these animals. Unfortunately the female is yet too young for breeding. The other heifer is in the zoological garden at Hamburg.

From recent information it appears that there remains in Sweden but one specimen, a cow born in 1900, and that the bull in Norway has also succumbed.

FROZEN MAMMOTH IN SIBERIA.[a]

By O. F. Herz.

[About the middle of April, 1901, the Imperial Academy of Sciences of St. Petersburg was informed by V. N. Skripitsin, governor of Yakutsk, of the discovery of a mammoth in an almost perfect state of preservation frozen in the cliff along the river Berezovka, the right tributary of the river Kolyma, about 200 miles northeast of Sredne-Kolymsk (about 800 miles westward of Bering Strait and some 60 miles within the Arctic Circle).

Thanks to the courtesy of Finance Minister Witte, 16,300 rubles were assigned for the prompt dispatch of an expedition to examine and secure this valuable find.

O. F. Herz, a zoölogist of the Imperial Academy of Sciences, was appointed chief of the expedition; E. V. Pfizenmeyer, a zoological preparator of the same institution, and D. P. Sevastianoff, a geological student of the Yuryevck University, his assistants. The expedition started from St. Petersburg on May 3, 1901, and its chief reached the mammoth region on September 9. On August 28 the expedition was joined by Mr. Horn, a police official from Sredne-Kolymsk.]

August 31–September 5.—Upon reaching Mysova, on the Kolyma River, I was informed that the Cossack Yavlovski had but a few days previously gone to the mammoth region, about 85 miles distant, having understood that the academy expedition would not reach Sredne-Kolymsk before winter, and that upon his return, in three or four days, I should be able to continue the journey. Yavlovski arrived on September 3, and though the tidings he brought were somewhat discouraging, there was yet hope for success. He had intended to visit the mammoth region in the spring, but had been hindered by serious illness, from which he only recently recovered. Were it not for this mishap he would have covered the find with stones and earth, and thus prevented it from injury by rain and beasts of prey. Owing to

[a] Extracts translated from report of O. F. Herz, chief of the expedition of the Imperial Academy of Sciences of St. Petersburg, to the river Berezovka for excavation of frozen mammoth. Entire report in Russian in Bulletin of the Imperial Academy, St. Petersburg, April, 1902 (fifth series, vol. XVI, No. 4). All dates are in old style.

unfortunate circumstances, Yavlovski tells me that rains during the summer had washed a mass of earth down the slope in which the mammoth lies, so that bones were torn from the hind part of the body, the entire back was exposed, and most of the head skin was devoured by bears and wolves. At the first examination the trunk was already gone. Yavlovski reported that he had collected all the bones lying about, placed them on top of the animal, and covered all with earth and stones, so that no more damage would be likely to result before my arrival. As he saw no hair or wool on the exposed parts, he thought that either there had been none or else it had been washed away by the rains.

I am very sorry I could not see the Lamut, S. Tarabykin, who discovered the mammoth, but he was absent at this time. I can therefore give the details of the discovery only as related to me, as follows, by Yavlovski: About the middle of August, 1900, while the Lamut Tarabykin was chasing a deer, he found a mammoth's tusk, weighing about 166 English pounds, a little above the present find, and continuing the search soon discovered the well-preserved head of a second mammoth protruding from the ground, upon which, however, there was but one tusk. On account of the superstitious fear that the Lamuts have of whole mammoth bodies, whose excavation they believe produces sickness, Tarabykin returned to his tent, about 15 miles distant, and told of his discovery to the two Lamuts, M. Tapchin and V. Dietkov. These two men visited me twice at the place of discovery, and after persistent inquiry informed me that at the time of finding the animal the skin upon its head had already partly decayed, and that there was no trunk, or "nose," as they described it. The Lamuts said that at the part where they chopped off the tusk, on the day following the discovery, there was left only a small piece of decayed skin. They believed that the head had been exposed for about a year before they found it, but insisted that they had never seen it before, as it was the first time they had visited the place, and that in general they had never before in their lives seen a mammoth. We must observe that the Lamut Tapchin was over 90 years old.

At the end of August, 1900, all three Lamuts repaired to Kolyma, where they sold the two tusks to Yavlovski, telling him that the smaller tusk, weighing a little over 63 pounds, belonged to a mammoth which was probably still in the ground in a good state of preservation, but which they dared not touch. The Cossack Yavlovski, being the more intelligent man, understood the importance of this discovery and agreed to meet them on the 1st of November and go with them to see the mammoth. He told the Lamuts that if what they related was true he would report it to the Emperor, which might result in the fitting out of an expedition to transport the entire animal to St. Petersburg. This satisfied the Lamuts, but it is to be regretted

that Yavlovski did not then instruct them to cover the mammoth with earth.

Early in November, 1900, Yavlovski, accompanied by the Lamuts, visited the mammoth. He cut a piece of skin from the head, a similar piece from the left thigh, and secured a small portion of the stomach, with its contents, and brought these, together with the tusk, to Sredne-Kolymsk as proofs of the discovery, giving them to the assistant police commissioner, N. L. Horn, who decided to convince himself of the importance of the find and then to report the matter to the governor of Yakutsk. The parts mentioned were therefore forwarded to the Imperial Academy of Sciences at St. Petersburg, where they were due after our departure.

In the middle of December, Horn and Yavlovski together examined the mammoth and reported the matter to the governor of Yakutsk, who in turn forwarded Horn's report to St. Petersburg.

September 11, 1901.—It was so warm to-day that the soil became loose and easily handled, and I was able to begin the work of excavation. The mammoth is located a third of a mile from our tents and 35 meters above the present level of the water, on the left bank of the river Berezovka. The body lies in a cliff that faces east and extends for a mile in a semicircle. The demolished portion of the cliff inclines toward the river at an angle of 35° from the upper layer of earth, over which extend the "taiga," or Siberian marshy forest. The surface of the cliff is 113 meters wide and 55 meters high. The body of the mammoth is 62 meters back from the bank of the river. According to measurements I took in different places the upper strata of earth, covered with a layer of moss, is 30 to 52 centimeters thick. Beneath this is a loamy mass, one-third loam and two-thirds earth, averaging 2 meters in thickness, though in some places more than 4 meters thick, mixed with stones, roots, and pieces of wood, with lamellar plates of ice, 15 to 18 centimeters thick, stretching through the mass. Underneath this alluvial layer there is a vertical wall of ice, which stands free for a distance of 5 meters, and in some places even 7 meters above the mammoth. This ice wall probably inclines to the river at the same angle as the entire cliff region. I intend to investigate this wall later. Upon this supposed ice incline are huge shapeless earth masses and mounds, evidently moved downward during heavy rains by the gradual thawing of the ice wall, as well as by the water which falls from the upper "taiga" and from the hill, 120 meters high, that rises in the rear of the wall about a sixth of a mile from the river bank. According to the Lamut natives of the region, the head of the mammoth was exposed two years ago by this downward movement, or by the breaking away of a considerable mass of earth; the rest of the body was exposed only at the end of August, 1900.

After taking some pictures I commenced to open up the mammoth mound. The skull was soon exposed. Unfortunately most of the head skin had been devoured by carnivorous animals during the past summer. To my greatest surprise I found well-preserved food fragments between the teeth, which serves as proof that our mammoth, after a short death struggle, died in this very position. The fact that what we found was food and not substance carried in recently was later proved by comparing it with the stomach contents.

Upon the left half of the bone between the jaws I could see marks of the ax which the Lamuts used in chopping off the tusk, and could thus determine definitely that the tusk that I had seen in Sredne-Kolymsk was from this particular mammoth, for I had carefully measured and studied the cuts upon it. The right tusk evidently had fallen out long ago, for I could find no traces of its forced severance from the head. The lower jaw, which was fast in the ground, lay upon a large piece of skin, which appeared later to belong to the upper part of the chest.

I first gave orders to carefully remove the mound of earth about the mammoth, beginning with the head. At a depth of 68 centimeters we found the left fore leg, still covered with hair on all sides up to the humerus. The epidermis had apparently completely rotted, but on account of the moist earth the hair still clung to the skin. In a frozen condition we may perhaps succeed in getting it to St. Petersburg.

So far as a preliminary examination can determine, the hair on the upper part of the left fore leg consists of a yellowish-brown crumpled under coat 25 to 30 centimeters long, with a thick upper bristle-like coat, the hairs of which have ragged ends, are rust-brown, and 10 to 12 centimeters long. The left fore leg is bent, so that it is evident that the mammoth tried to crawl out of the pit or crevice into which he probably fell, but apparently he was so badly injured by the fall that he could not free himself.

Further excavation exposed also the right fore leg, which had become turned almost horizontally under the abdomen during the animal's fall. Only a very insignificant portion of the upper bristly coat was preserved upon this leg, while the yellowish-brown under coat was preserved in several places. Upon the left hind leg I also found portions of decayed flesh, in which the muscular bundles were easily discernible. The stench emitted by this extremity was unbearable, so that it was necessary to stop work every minute. A thorough washing failed to remove the horrible smell from our hands, and yet we were obliged to perform part of our task with bare hands.

September 12.—After we removed the earth from under the left leg the thick hair on the under side came to view, especially that on the foot joint. Some of this hair fell off with the earth, but the larger

Ice Wall on the Bank of the Beresovka River, where the Mammoth was Found.

THE POSITION OF THE BODY OF THE MAMMOTH (HEAD AND FORE LEGS) ON THE CLIFF.

part will be saved by bandages. In the midst of the yellowish-brown under wool, which in color resembles the summer coat of a young camel, there are very thickly set hairs of the bristly coat 10 to 12 centimeters long. The color of this hair on the under side of the leg may best be described as roan, while that on the outer and inner side up to the middle of the forearm is dark brown, somewhat lighter at the ends. Five hoof-shaped blunt nails could also be seen at the end of the digits.

The wool of the left hind leg, varying in color from rust-brown to roan, was not so thick as upon the fore leg, judging by the loosened remains of the hair, and the yellowish-brown under coat was here a little shorter. The length of the ragged end hairs varies from 4 to 12 centimeters. The roots of the hair had rotted away together with the epidermis.

After midday we dug away the mound of earth to a depth of 2.4 meters on the right side of the mammoth. In the mound, lying between the upper layer of earth and the vertical ice wall, roots and other parts of trees and also bowlders were found lodged. Under this layer of earth, 2½ meters thick, I first struck water ice 18 centimeters thick, caused by a thaw; then a thin layer of earth; under this again another layer of ice, and then the right fore leg of the mammoth came to view. The wool that had probably covered the upper side of this leg was entirely gone, most likely torn away by the sliding masses of ice and earth. The same was true of the wool on the other sides of the animal.

The right fore leg was so placed as to indicate that the mammoth after falling had supported himself on this leg while attempting to step forward with the left one. We concluded that while in this standing position he became exhausted and died on this very spot, and that he had by no means been washed there by the water from elsewhere. The presence of a thick wool shows that the animal was well adapted to endure cold, and it is improbable that he died from hunger, for a large quantity of fragments of food was in his stomach. His head faces south.

September 13.—To-day we took photographs. I searched the vicinity for bones of other animals and found horns of the northern deer lying about everywhere.

September 14. In an effort to find remnants of the trunk, I ordered that the mound be opened up farther south and southeastward, but I did not find them. This part was no doubt exposed before the rest and had long ago either decayed or been devoured. I examined every shovelful of earth, but I found only indefinite fragments of very brittle hair, and that was all.

A bone found 1.82 meters to the south of the right cavity was subsequently determined to be a part of the skull of a northern deer.

After dinner I began clearing the ice away from the right side. Near the outside of the right fore leg the ice was brownish in color, with bubbles, and 23 centimeters thick, and 27 centimeters thick over the sole of the right fore foot, which also faced the south, as did the left hind leg. Beneath both legs there was a layer of ice 3 centimeters thick, which, after the final loosening of the animal, was found to extend beneath the entire body. From the right hind leg northward, in the direction of the highland, the ice ran thicker, being at first 54 centimeters, while 86 centimeters from the sole it was 71 centimeters thick; then came the earth layer. The ice layer, 71 centimeters at its thickest part, extends to the middle of the right side of the abdomen, where it becomes 10 centimeters thick.

A very interesting discovery was made at a distance of 13 centimeters from the upper edge of the sole of the right hind foot, namely, the very hairy end of the tail, which was subsequently thawed out and examined. (See September 21.)

September 15. The snow has completely disappeared off the cliff. I stopped further excavation, however, in order to resume it when my companions, who were left behind, shall arrive and Mr. Sevastianoff can make the geological survey. In order to be able to dismember the mammoth after severe cold weather has set in, I am disposed to build over the animal a structure that can be heated, and for this purpose I will order, one of these days, the cutting and planing of timber. Meanwhile I covered the animal with tarpaulin to protect it from possible snowing under.

September 16.—During clear weather I made a trip to the top of the hill eastward of here and brought from there some specimens of mountain flora. I append a sketch of the Berezovka as seen from there.

September 17. The cliff region extends along the loop made by the Berezovka and along the deep channel of this river a half mile farther south, where it gradually becomes lower. During spring high tide masses of earth are detached from the cliff.

Further geological research will determine how the cliff region was formed, and yet, although I am not a geologist, I regard it my duty to here express my personal views. According to my opinion, the entire cliff region rests upon a glacier, which was disintegrating and in which there were deep crevices. The water that flowed down from the "taiga," or from the neighboring hills, mixed with earth, stones, and pieces of wood, gradually filled these crevices. The whole was later covered with a layer of soil, upon which a rich flora doubtless developed that served as excellent food for mammoths and other animals. Whether this flora was identical with the present flora can be determined only when the food fragments found in the mouth and stomach of the mammoth shall have been examined and compared with the

SIDE VIEW OF THE MAMMOTH AFTER PARTIAL EXCAVATION

THE MAMMOTH AFTER PARTIAL EXCAVATION, SIDE VIEW FROM THE EAST.

plants I collected on the cliff. The upper layer of earth was at that time probably not yet everywhere firm enough to support the weight of mammoths, and probably our specimen broke through into a crevice, which would account for his position and for the fracture of such heavy bones as the pelvis and the right forearm. After falling,

Fig. 1.—Map of the region where the mammoth was found. 1. The river Kolyma. 2. The settlement of Mysova. 3. The river Mysovka. 4. A small stream. 5. First night quarters. 6. Mount Blindo. 7. Hill, 420 meters above sea level. 8. Second night quarters. 9. Hill, 375 meters above sea level. 10. Third and fourth night quarters. 11. River Beresovka. 12. River Siver. 13. Place of finding the mammoth. 14. River Kuchurata. 2–13. Route from Mysova to the place of finding the mammoth—about 85 miles. The dotted line marks the return route.

the mammoth no doubt tried to crawl out, the position of both fore legs being peculiarly like that of an animal making such effort, but the injuries were so serious that his strength gave way and he soon perished. The pit, 4 meters square, dug with the spade after the mammoth was removed, showed that the ice wall must be quite deep.

probably reaching below the channel of the river. At a depth of 1.7 meters in this pit I found ice similar to that of the upper part of the ice wall.

About 100 meters north and even lower than the mammoth's grave there is an ice cliff covered by a layer of earth 2½ meters thick and structurally identical with the upper wall. The exposed ice is brownish earthy in color and contains numerous air bubbles, some of them elongate, averaging 2 to 5 millimeters in length; others spherical, averaging 1½ to 2 millimeters in diameter. Among the bubbles, which are often connected, there are thin layers of sand or clay that in places form small lumps. Deeper down in the cliff the ice becomes more solid and transparent, in some places entirely white and brittle. After remaining exposed to the air even for a short time this ice again assumes a yellowish-brown color and then looks like the old ice. The ice, on the other hand, which is formed from melted ice and snow is always transparent, white, and hard, and on account of the longer vertical air bubbles, which attain a length of over 20 millimeters, assumes a streaked appearance.

That the ice wall was formed from snow I regard as unlikely, because the entire mountain faces directly east, and throughout summer is subjected to the sun's rays to such an extent that a considerable portion of the snow must have been melted by these rays as well as by the heated mass of stones of the neighboring mountain crest. Do we not see here before us primitive or, as Baron Toll puts it, stone ice, which resulted from the previous glacial period?

It is difficult to presume here the formation of a glacier valley that could have attained a height of 50 meters, for such a damming of the water as would cause the formation of a valley can not be admitted when the depth of the Berezovka is taken into consideration.

September 18.—To-day we moved from the tents into the new winter house, built under my instructions in the woods, in a place protected from the northern winds. Toward evening we succeeded in establishing ourselves and felt quite comfortable, supping near the fireplace in a well-warmed room.

September 19.—In several pits in the earth I found well-preserved parts of *Betula nana*, which no longer grows upon elevated places, though in well-protected spots one occasionally finds stems about as thick as a man's arm.

The timber assigned for the building of a house over the mammoth is already cut and prepared and we can commence putting it up as soon as our fellow-travelers arrive.

Despite the fact that the mammoth is in a frozen condition, the stench emitted is very disagreeable.

September 20.—At the exact hour of my prediction Mr. Pfizenmeyer arrived this afternoon with the rest of the transport equipment. To

SKULL OF THE MAMMOTH WITH FOOD REMNANTS (*f*) BETWEEN THE MOLAR TEETH

LEFT FOREFOOT OF MAMMOTH.

FIG. 1.—RIGHT HINDFOOT OF MAMMOTH.

FIG. 2.—LEFT FOREFOOT OF MAMMOTH.

my surprise. Mr. Sevastianoff was not with him, as he returned from Mysova to Sredne-Kolymsk, together with Mr. Horn.

September 21.—To-day, in the winter house, we began to thaw out the tail end, which we found on the 14th instant, but soon stopped the work as all the hair threatened to fall off. This tail end is 22 centimeters long and the hairs at the extremity, penetrating an icy-earth mass, are 10 centimeters long. The hairs stand in bunches around the end of the tail. When warmed, however, these separate from the skin, together with the epidermis, only at the very end. Part of the hair is still fast in the skin. The hairs on the basal end of the tail and a little farther down are dirty yellow ocher in color, while those at the distal end are black. The thin ends of the hair are partly broken off. The hairs at the middle of the tail end are a very few centimeters longer than the others, and their color is ocher at the base, then black, and at the very end passes into whitish.

September 25.—The building over the mammoth is fast advancing toward completion. As we proposed to build this structure below the upper wall of the skull, we removed the latter, after which we could take out the remnants of food from between the molars on the left side. These remnants appear masticated and apparently do not contain parts of pine needles or larch, but only fragments of various grasses. The imprint of the tooth crenations is well preserved upon the food bits. There is also a small quantity of food upon the well-preserved tongue, but I can secure this only when the lower jaw is removed.

The most devoted mother could not carry her child more carefully than I carried these fragments of antediluvial fauna to our winter hut.

When the Lamuts discovered the mammoth they could not see the fragments of food, for the lower jaw was then still in the ground. This was confirmed by Tarabykin's companions, whom I questioned closely on this point.

September 26.—To-day I took the principal measurements of the mammoth as they are given in the accompanying drawings. I also collected the plants that are partly under the snow.

September 28.—To-day we finished the roof of the house over the mammoth.

September 30.—To-day we made the first experiments in heating the house, and the arrangement appears to be excellent. However, we have yet to build a wooden partition, so that the animal may not be exposed directly to the fire, however low it may be. But in order that the mammoth should not freeze it is necessary to keep a steady fire day and night.

October 1.—As it was found too dark in the house, a second opening was made near the door. To serve as window panes we placed pieces of ice in both openings and hung an elk's skin over the door.

October 2.—We began this day to clear the earth away from the occiput and back. Doing this we exposed several broken ribs. We also dug up several lumbar vertebræ which had been torn out by wild beasts or else forced out by the sliding earth.

Under the right middle part of the abdomen, which was still covered with earth, we found a yellowish-brown underwool 20 to 30 centimeters long, which, however, was so crumpled and mixed with earth that we saved only a small portion of it.

We also collected and deposited in a bag the underwool and bristles from the right cheek. The latter are 20 centimeters long and broken

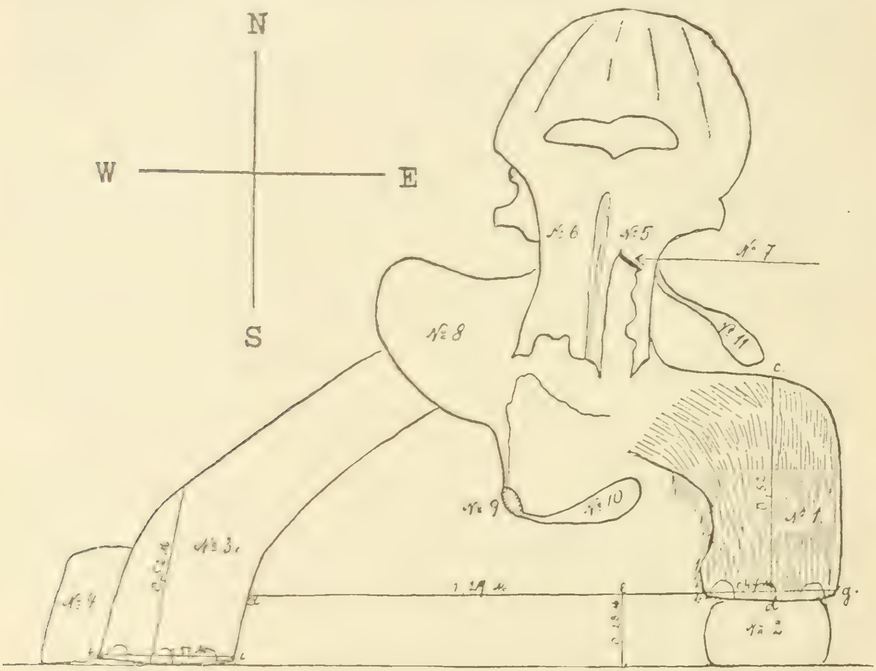

FIG. 2.—View of mammoth from the South, Sept. 25, 1901, distance 4.5 meters. $a-b=1.29$ M.; $c-d=0.52$ M.; $e-f=0.28$ M.; $b-g=0.44$ M. (sole of foot); $h-i=0.37$ M. (sole of foot). 1. The left foreleg and hair. 2. The left hind leg. 3. Right fore leg. 4. Right hind leg. 5. Left tooth cavity. 6. Right tooth cavity. 7. Ax incision. 8. Part of cheek skin. 9. Eye. 10. Under skull epidermis. 11. Skin.

off at the ends; the color varies from black to pale blonde; the black hairs predominate, and are lighter toward the ends.

October 3.—After removing the last layer of earth from the back, the remains of food in the stomach were exposed. The latter was badly decayed. We could not continue our work here owing to the solidly frozen condition of everything. After dinner we removed the right side of the abdomen in order to permit the access of heat from the fireplace into the interior of the body.

October 4.—Before noon we removed the left shoulder blade and

part of the ribs, and then cleaned part of the stomach, which contained an immense quantity of food remnants. The walls of the stomach first exposed were dark coffee-brown, almost black in color, and were badly decayed and torn, even where they were not injured mechanically.

In the afternoon we severed the left fore leg between the shoulder and forearm in hopes of saving the wool, which still clung to the leg, and which might have fallen away during subsequent thawing. Besides, this amputation was made necessary by the left side of the abdomen.

October 5. To-day we first skinned the left side and exposed several ribs, which were mostly very well preserved. The stomach with its contents is becoming more and more exposed, while the other organs are destroyed. Then we skinned the head, of which the following parts were preserved: The cheeks, the right eyelid with the deep eyelash fold, part of the skin from the sinciput, three-fourths of the upper lip, and the very well-preserved under lip. This latter was also beset by scattered spines or bristles, which, however, adhered to the ground and were mixed up with other hair, so that it was impossible to pick them out. The skin from the head, which was already decayed in several places, we immediately treated with alum and salt.

In the afternoon we removed the left shoulder, upon which, however, we allowed the tendon and muscular fibers to remain.

The flesh from under the shoulder, which is fibrous and marbled with fat, is dark red in color and looks as fresh as well-frozen beef or horse meat. It looked so appetizing that we wondered for some time whether we should not taste it, but no one would venture to take it into his mouth, and horseflesh was given the preference. The dogs cleaned up whatever mammoth meat was thrown to them.

The layer of fat beneath the skin is 9 centimeters thick. It is white, odorless, spongy, and readily cut. The flesh between the ribs and skin, as well as the membrane under the ribs, could easily be pulled off in separate layers without special effort.

The skin on the left shoulder is 19 millimeters thick, and on the right side 23 millimeters.

The big bunches of hair that stuck in the frozen ground near the lower lip, and which belonged to the chin and chest, are 36 centimeters long, torn as they are. Estimating the broken-off ends to be one-third the entire length (based on the thickness of the hair at the break), we may assume that these hairs were approximately 50 centimeters long. The bristly hairs which stuck in the ground immediately behind the lower lip are black, while those pointing to the fore legs are ash-blonde in color. In view of the fact that it is impossible to pick out these hairs uninjured, I shall save the entire clod of earth in a frozen state.

Of length similar to that of the above-mentioned hairs is the hair shed from the outer side of the left shoulder blade, which I removed. Judging by the remnants of the separate hard bristle-like hairs that I observed on the skin, they were of the same length, extending perhaps along the back. Beginning with the destroyed epidermis, up to the very ends, these hairs are ashy or pale blonde in color. The shoulder bore the longest hair found thus far, and is probably what has been erroneously called the mammoth mane. The applicability of this name will be possible only when it shall be proven that no other part of the mammoth was covered with such long hair.

The hairs upon the belly are reddish-brown at the base, chestnut-blonde in the middle, and yellowish at the ends.

The hairs on the left cheek are 23 centimeters long, partly chestnut-brown to black, partly blonde. The under wool is not so thick as on the other parts of the skin, the hairs being yellowish as everywhere else, and 35 centimeters long.

The bristle-like hairs of the spine retain their elasticity so long as they remain in the fresh air, but in the temperature of our winter house they hardened instantly and became very brittle. I keep everything, therefore, in the fresh air.

October 6.—We bandaged the left fore leg, packed it in hay, then wrapped it in sackcloth, so that all the wool will probably remain intact. In Sredne-Kolymsk we shall, in addition, sew all these things up in skins, of which I have not enough here.

From the stomach we removed about 27 pounds additional of food remains. We then amputated the right fore leg above the shoulder blade, cut it open down to the forearm and removed the shoulder bone, which was broken in the middle, evidently injured when the mammoth fell. We would gladly have transported the leg intact, but for its too great weight for one dog sled. The flesh and fat are well preserved and will be packed for shipment. No hair was found on the outer and anterior sides of the right fore leg, and from the under side of this leg I succeeded in saving only what I found in beautiful layers in the ice.

I collected bits of blood, which resembled small pieces of potassium permanganate. When melted, these bits turn into dirty dark-red spots, which are easily washed off. To the touch they resemble coarse dry sand. Similar blood occurs also between the stomach and the sternum, whereas blood that was taken from above the sternum and the shoulder blades had a bright clay-yellow color, and to the touch felt like chalk. Separated by a layer of cotton, I put these two kinds of blood in a bag.

The stench is not near so intolerable as during the first two days, possibly because we have grown accustomed to it.

October 7.—To-day we first packed up the right leg and then resumed the cleaning of the stomach. Those parts of the stomach that were exposed to the air for any length of time tear even when most cautiously touched, exactly like the membrane beneath the ribs. I succeeded, however, in removing from the body a considerable portion of the stomach with its contents, which I take with me in a good state of preservation.

In the afternoon we succeeded in exposing that part of the body which we could not reach before, and which lay all the time in the frozen ground. This part was 9 centimeters lower than the left forearm, and 13 centimeters lower than than the sole of the left hind foot, and proved to be the protruded male genital, 86 centimers long above and 105 centimeters long below; 10 centimeters above the urinary meatus; the diameter of the flattened-out penis is 19 centimeters.

October 8.—The more the hind part becomes free the more difficult becomes the work. The left side of the broken pelvis was removed. The flesh beneath the pelvis is still frozen and hard as stone, just like the flesh about the shoulder blades. Near the stomach there is a lump of ice which we must remove little by little. The cross bone or sacrum was found intact.

October 9.—This morning we cut off the left hind leg and the right hind one this afternoon. The thigh bones, which were severed with great difficulty from the frozen meat that surrounds them, were so strongly connected with the tibia that it was necessary to cut all these bones out together and dismember them the next day.

The color of the hair of the right hind femur varies from rust-brown to black. Best of all preserved was the hair in the skin fold between the genital and the left hind leg. The crumpled hair of the under wool is 30 to 35 centimeters long; the bristly hair is 32 centimeters long. I saved some pathological growths from the right shoulder bone, also some layers of hair with exact descriptions as to their position on the body.

October 10.—After removing about 270 pounds of flesh we started the raising of the abdominal skin, which turned out to be still quite bulky and which we had decided must be cut up. After raising the piece of skin, which weighed about 470 pounds, we discovered, to our greatest joy, the entire tail of the mammoth, and by means of it explained the other puzzling point. The joy that possessed us at this new discovery was so great that, lowering the skin to the ground again, we gave three loud cheers. We could not decide to cut up the still intact piece of skin, as we wished to be able to bring this interesting object intact to the academy.

The tail is short, and consists evidently of 22 to 25 caudal vertebræ. It is not as long as the drawing made under Von Brandt's supervision.

and more nearly resembles the tail drawn by Boltunoff, though it defective in other respects.

The hard bristly hairs, which are broken off to about one-third thei length, indicate that the end of the tail was covered with long hair that became fastened in the layer of ice underneath the entire body These hairs were drawn out of the ice, however, with great care They are 20 to 25 centimeters long, and, like the bristly hair on the

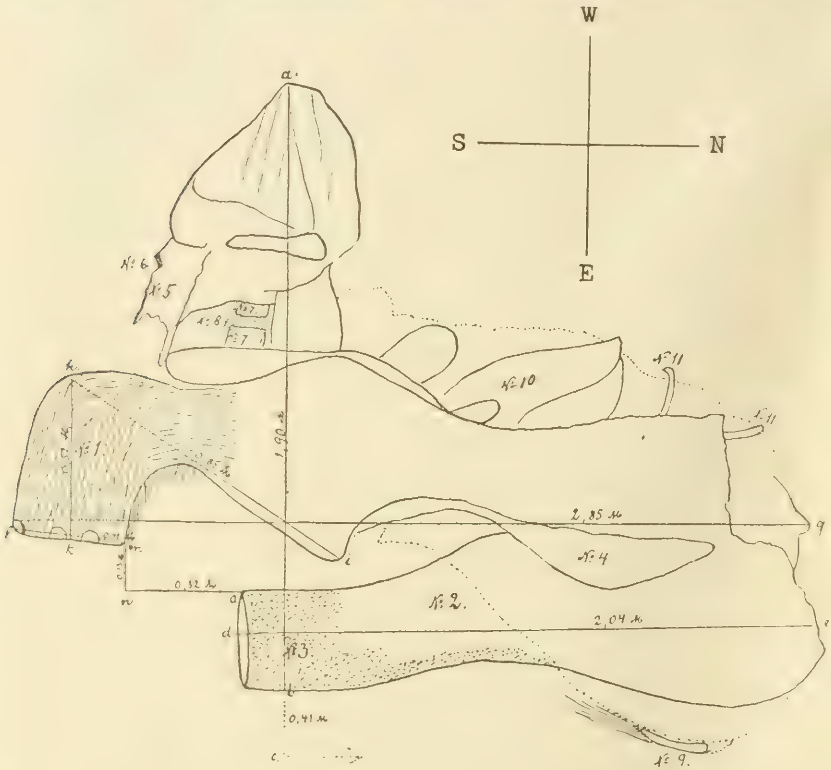

FIG. 3.—Side view of mammoth from the east. $a-b$=1.90 M.; $b-c$=0.41 M.; $d-e$=2.04 M.; $f-g$=2.85 M.; $h-i$=0.85 M.; $h-k$=0.52 M.; $l-k-m$=0.42 M.; $m-n$=0.13 M.; $n-o$=0.32. 1. The left fore leg and hair. 2. Right hind leg. 3. Under wool. 4. Abdominal fold. 5. Left-tooth cavity. 6. Incision of the ax. 7. Molar teeth. 8. Food remnants. 9. Tail. 10. Shoulder. 11. Ribs. The upper dotted line indicates the edge of the skin on the right side. The lower, the position of the skin of the abdomen and tail. The tail lies 41 centimeters lower than b. 1.9 meters below the tail was pure ice.

anterior side of the left fore leg, rust brown in color, their somewhat darker color being due to deterioration under the influence of dampness. Some of the hairs are half a millimeter in diameter at the base of the tail. On the under side of the tail they stood closer at the very end and sides. The length of the tail, measured on the under side, is only 36 centimeters, while its circumference at the base is 32 centimeters.

MAMMOTH FROM BERESOVKA IN THE ZOOLOGICAL MUSEUM IN ST. PETERSBURG, RECONSTRUCTED IN THE POSITION IN WHICH IT WAS FOUND.

FRONT VIEW OF MAMMOTH SKELETON FROM BERESOVKA, MOUNTED IN THE ZOOLOGICAL MUSEUM IN ST. PETERSBURG.

The width of the anal opening is 28 centimeters, and the length of the somewhat drawn-out skin extending between the base of the penis and that of the tail is 1.32 meters.

The base of the tail, together with the anus, were located 41 centimeters lower than the under side of the left hind tibia.

The reason that Boltunoff, in his drawing, figured excresences on the fetlocks, which indicate the presence of rudimentary metacarpal or metatarsal bones, is explained by the fact that the mammoth he saw in all probability had just such a mass of hair at the bend of the leg as this mammoth found on the Beresovka.

October 11.—To-day we performed the last operations on the mammoth, after which all the parts were brought into the winter house and securely packed away for transportation.

A SUMMARY OF GENERAL OBSERVATIONS ON THE SPOUTING AND MOVEMENTS OF WHALES.[a]

By Émile G. Racovitza.

To avoid repetition in the description of the habits of the different species which we have observed. I propose to group in this chapter a certain number of ideas relative to the life of the whales in general. There is much yet to be done on this subject. Many questions have not been answered, many even have not been asked. It will therefore be useful to sum up in the following pages what is known on this subject and what I have been able to observe myself, and to group the questions systematically.

Whales are terrestrial mammals that are modified for an exclusively aquatic life. The whale seeks its food in the water, but is obliged to breathe in the air. From these two facts springs all the very special biology of these creatures, as well as the characters of their organization.

My most numerous and, I believe, most novel observations have had for their principal object the necessary respiratory movements of whales. These movements are very regularly performed and very characteristic for each species. The greater part of this chapter will be devoted to them; the remainder will comprise a description of some other movements which have no bearing on respiration. I have entirely neglected their reproduction and manner of taking food, because I have had no personal experience on these matters.

Respiratory movements.

The respiration of land mammals is accomplished by means of inspirations and expirations succeeding each other at obviously regular intervals; but when a land mammal plunges into the water its respiratory rhythm changes. To a series of rapid inspirations and expirations there succeeds a very deep inspiration; then the respiration is suspended during immersion. Upon returning to the surface the diver makes a long expiration, succeeded by a series of rapid inspirations

[a] Translated by Frederick W. True from the Zoology of the Voyage of the *Belgica*, Cetology, 1903, pp. 5–19.

and expirations. This respiratory rhythm, which land mammals utilize only accidentally, forms the normal rhythm of the respiration of the whales, and, I may add, of all terrestrial vertebrates which are modified for an exclusively aquatic life (for example, the leatherback turtle, the water snakes, etc.).

The whale, having returned to the surface after a long immersion, emits then a prolonged expiration, makes a short inspiration, dives a little, reappears to breathe, dives again, and thus many times in succession; then he makes a long inspiration and plunges into the depths for a considerable time. I will now analyze successively all these movements.

A.—EXPIRATION, OR "SPOUT."

This is the only part of the act of breathing which has attracted the attention of the whalers, and they have given to it the special name of "souffle" in French, or "blow" or "spout" in English.

1. The moment at which the "spout" is produced.—Expiration is produced exactly at the moment when the summit of the head, on which the blowhole is placed, arrives at the surface. Therefore, in general, it is the protuberance of the blowhole which indicates the presence of the animal. It is, moreover, at this moment the most prominent part of the body, because whales have the faculty of protruding this part of the blowhole. (I have proved this for the whalebone whales, and it is probably true of the toothed whales.) The movement of the protuberance of the blowhole is very rapid, and Buchet (1895) is the only one who has pointed this out. Whalers told him, indeed, that when a whale blows "the blowhole forms a very large protuberance," which disappears when the animal is dead.

In *Balænoptera musculus* L. (the sulphurbottom) the median region of the back often appears before the protuberance of the blowhole. In the sperm whale that which appears first is the dorsal [hump?], according to the opinion of Beale (1839), who appears to have carefully observed these animals. As to the porpoises and the ziphioid whales, it is possible that their blowhole is not extensible, but it is also the top of the head which appears first above water.

2. Duration of the spout.—The duration of the spout is variable and depends on the size of the whale. The large whales spout longer than the small ones, and the first spout after sounding is much longer than the intermediate spoutings. I have estimated it at five or six seconds for *Balænoptera musculus* L. (the sulphurbottom) and at three or four seconds for the humpbacks. Beale (1839) mentions six seconds for the sperm whale. As to the porpoises, the duration of their spout does not exceed two seconds. Whatever the length may be, the spout always lasts longer than the inspiration. I will return to this subject in connection with the second part of the respiratory act.

3. *Noise of the spout.*—The noise produced by the spout is also very variable in intensity, in accordance with the size of the animal. Scarcely perceptible in *Delphinus delphis* L. (the common dolphin) and its allies, it becomes very loud in the small finbacks, louder still in the right whales and the humpbacks, and of a force truly extraordinary in a *Balænoptera musculus* L. (sulphurbottom) of great size. This sound has been compared with good reason to the noise made by steam escaping from a pipe under pressure; from a brass pipe, I may add, because very often the spouts of the finbacks possess remarkable sonorousness. It is not a true emission of voice, because whales have no vocal cords, but a simple vibration caused by the expulsion of air under pressure. The effect is often produced even in man when the nose is for any reason obstructed by foreign substances. It is not rare, indeed, to observe whistling sounds which, with a due allowance for difference in proportions, are of the same nature as the more or less musical sounds produced by whales. It is in this way that I explain the bellowings so often described as occurring among cetaceans. I ought, moreover, to mention that among certain porpoises it may be that there are special dispositions of parts which produce noises in a constant manner.

4. *Form and appearance of the spout.*—The form and appearance of the spout depend much on the force with which the air stored in the lungs is expelled; they depend also on the rapidity of motion of the animals and the state of the atmosphere. Among small whales the spout is invisible, or very little visible, and the whale must exceed at least 10 meters before its spout will be visible.

The appearance of the spout is that of a mass of white and pearly vapor. When it is calm and cold and when the whale is quiet or moves gently, the spout rises vertically in the air in a column more or less slender according to the species. The right whales emit a very large spout and the finbacks a small one. As the upper part of the column becomes enlarged the spout takes the form of a very much elongated cone, but before the end of the expiration the summit of this elongated cone spreads out, its outlines become vague, and the terminal part is transformed into a sort of cloud. At the end of the expiration the spout detaches itself from the blowhole, rises gently in the air, and the lower part disappears; it seems to gather itself together into the upper cloud, and finally the upper cloud also dissolves. This is noticed especially in the case of the first spout after sounding, which is always more forceful.

On the other hand, in expirations during the intervening appearances at the surface the column formed by the spout is less high, the cone which it forms is much less elongated, and its duration in the air is much less. When the wind blows or when the animal is in rapid

motion, the column inclines backward and takes on the appearance of a glass tear.

Ancient authors often figured the spouting of different species of whales, but these figures are as naïve as false. One sees that these venerable cetologists believed that the whales threw up water through the blowhole, because their figures reproduced conscientiously the appearance of jets of water and fountains gushing. Baer (1864) was the first to give a figure obviously exact of the spout of a finback and of its transformations. He has, nevertheless, drawn it too cylindrical. In reality its form is distinctly conical. Henking (1901, figs. 1 and 2) has perfectly given the appearance of the spout of a *Balænoptera physalus* L. (common finback), and the inclination which he has given it is certainly due to the rapid progression of the animal.

The highest spout is that of *Balænoptera musculus* L. (the sulphur-bottom), in spite of what Rawitz (1900) says, who only attributes to it 1 meter. All the eyewitnesses agree on this subject, and I estimate further on the height of the spout of this animal at favorable times at 15 meters (49 feet).

The largest spout is that of *Balæna mysticetus* L. (bowhead). The right whales, finbacks, and humpbacks throw up vertical spouts in calm weather, the sperm whale spouts inclined forward at 135° (Beale, 1839), and the large porpoises a very short spout, also inclined.

One reads often in authors that the spout of the finbacks and the right whales is double, but if one goes to the sources—that is, to the writings of eyewitnesses and not to those of compilers—one sees that nothing is in general less proved. Beale (1839) declares plainly that the spout of the sperm whale is simple and is distinguished on that account from the spout of the other whales, which is double, but this seems to apply only to the right whales. Thiercelin (1866, vol. 1), who seems to have been a conscientious author, declares expressly that the southern right whale throws "a double column of white vapor, more or less thick, which rises in the form of a V, of which one branch is shorter than the other." Other observations seem to confirm this.

It is otherwise with *Megaptera* (humpbacks) and *Balænoptera* (finbacks). Baer (1864) declares that he has observed that the spout of *Balænoptera* is simple, and that, moreover, one only sees it double in looking at the animal from in front. Rawitz (1900) has also seen the spouts of the humpbacks and of *Balænoptera musculus* and *physalus* single. Henking (1901) also figures it single in *B. physalus*. I have always seen it simple, although humpbacks and finbacks have spouted very near to me, both front view and in profile.

It seems to me that we have to do here with an a priori idea, suggested by the fact that these whales have two openings in the blowhole. But as these openings are very near together, and as the diameter of the column formed by the spout is relatively considerable, it seems to me

difficult to believe that the spout of each orifice can preserve its individuality. It is not possible, then, to see them separately, even when one observes the animal from in front, the only position in which one can theoretically distinguish this duality.

5. *Nature of the spout.*—The greatest uncertainty has reigned for a long time as to the nature of the substance thrown out by the whales when spouting. Aristotle (History of Animals, VIII, 2) declares that "at the same time that it (the dolphin) takes in the water and ejects it through its blowhole it has a lung, through which it receives the air and breathes." The real nature of the cetaceans was thus established at this early day, but at the same time also the idea that these animals throw out water through their blowholes. Pliny (Natural History) did much to cause this last belief to be adopted by citing some definite cases. He shows the "physeter * * * diluviem quandam eructans." (Liber IX, cap. IV.) He even mentions having seen a killer whale fill and swamp a boat with his spout,—"quorum unum (navigium) mergi vidimus, reflatu belluae oppletum unda." (Liber IX, cap. VI.)

Although this idea is absolutely false, it was adopted without discussion, and only at the beginning of the nineteenth century was the notion abandoned, not, however, without contest and without its reappearance from time to time. Thus F. Cuvier (1838) still admitted it. And actually even Bruce (1896), who was the naturalist of the *Balæna*, maintained it, and Dahl (Henking, 1901, p. 3, note 7) is said to have established it very recently in the case of a cetacean which he believed to be a sperm whale.

So far as I know, it was Fabricius (1780), the conscientious observer, who first expressly said that whales expel only air charged with vapor, and, following him, I will mention, among those who are authorities in cetology and have themselves observed cetaceans, Scoresby (1820), Baer (1826 and 1836), Beale (1839), Bennett (1840), Holböll (Eschricht, 1849), Baer (1864), Thiercelin (1866), Brierly, Haglund, Torrell (Lilljeborg, 1866), Scammon (1874), and all recent cetologists.

The proofs that whales do not expel water through the nostrils, but air saturated with vapor, like all mammals without exception, are many and of different kinds. I will give a brief summary of them, taking notice of those already given by cetologists and adding those derived from my own observations.

The spout has neither the form nor the appearance of a jet produced by water escaping under pressure, but very much the flocculent appearance of a cloud. It is seen that this cloud is blown along by the wind, like ordinary vapor; it is seen to spread out and dissolve in the air and not to fall in a cascade as it would if it were water. It is absolutely impossible for a conscientious observer to doubt the

reality of these evidences, however little he has witnessed whales blowing close at hand. An observation of this kind alone should suffice to decide the question, but I have another proof furnished by a more direct observation. On January 28, 1898, the *Belgica* was in Charlotte Bay (Gerlache Strait). We were surrounded by a great school of humpbacks, and I located myself with the photographic apparatus on a stage which projected about 2 meters over the gunwales of the ship. One of the humpbacks came up suddenly under the stage to spout, and I was entirely enveloped in the animal's expiration. Under these conditions I was well situated to know whether the humpbacks eject water or air. I can assure Dahl, Bruce, and all who persistently remain followers of Aristotle and Pliny that there was not the least bit of water in the expiration of this whale. I was struck in the face by a warm and humid wind of a fetid odor, to the consideration of which I shall return later on.

The anatomical structure of the larynx, of the back of the buccal cavity, and of the blowhole prohibits the expulsion of water. We know, indeed, that among all the cetaceans the extremity of the larynx is prolonged into a very long appendage, which, penetrating deeply into the canal of the blowhole, completely fills the cavity. This arrangement is a marvelous adaptation to the necessity which there is for whales to swallow their prey under water. The respiratory organs are thus completely separated from the digestive organs in the back of the buccal cavity, the food passing into the esophagus on each side of the larynx, while the water or the substances with which it is filled are not able to penetrate into the larynx. This being established, it is not easy to see how the water can be expelled through the blowhole, which is completely closed. On the other hand, one asks in vain what may be the force which could project this water to such considerable heights as are observed in the case of some spouts. How is the whale able to produce the necessary pressure in its mouth? The conformation of this cavity does not permit, in fact, a complete closing of the mouth even among the toothed whales; on the contrary, it is formed in such a manner as to allow the passage of water. The whalebone whales have in the corners of the mouth veritable gutters, which are especially well developed in the humpback and are useful to these animals in expelling the water in which their food floats.

Thus, in order that the water may be thrown out through the blowholes to a great height, it is necessary that it be previously held in the lungs. I believe that even the most fervent partisans of Aristotle's ideas would recoil before such a supposition.

But there is one case in which a liquid is thrown to a considerable height through the blowholes. That is when the whale is wounded in the lungs. In this case a jet of blood is often thrown to great height.

This phenomenon is not peculiar to whales: it is presented by all animals whose lungs are torn or for any reason filled with blood.

Many conscientious observers, however, think they have proved that the spout sometimes falls in drops of water. Baer (1864) says that Captain Kotzebue has seen a whale spout so near the ship that the spout spread out over the deck, which was covered with little drops, but these drops were never sufficiently numerous for the water to collect in a stream. Thiercelin (1866, t. 1) relates that from the spout of the right whale there fall some small drops of "oily matter" and a certain quantity of water. Lilljeborg (1866) cites Haglund, who has seen drops of water fall from the lower part of the cloud formed by the spout, and Torrell, who declares that a little water fell from a spout onto the deck of the ship, the water probably produced, he adds, by condensation of the vapor.

All these observations, and others which I have not cited, have been made in the polar regions, where the temperature of the air is very low. They could therefore be explained easily by the very rapid condensation of the water contained in the spout.

Many other explanatory hypotheses have been put forward. It is claimed that the animal having blown before the protuberance of the blowhole is completely emerged, the spout draws with it a part of the surface water and vaporizes it. Baer (1864) does not admit this view. He observes, very justly, that whales do not spout until the blowhole is out of the water. On the other hand, the results of an experiment which he made appeared to him conclusive. He blew under water with a curved tube and proved that the water was not carried up except when the orifice of the tube was very close to the surface.

It seems to me that the experiment of Baer demonstrates just the opposite of what he claims. He has, indeed, demonstrated experimentally that water can be drawn up under certain conditions, and one can hardly suppose that these conditions are never realized; on the contrary, it is very probable that they may be sometimes realized. Baer himself figures a killer which draws up some little drops of water with the spout. I believe, then, that such occurrences are possible.

But many authors, and Baer among others, have proposed a different explanation. They also believe that the small drops of water which fall from the spout are from water drawn up, but derived from that which accumulates in the depression of the blowhole. Rawitz (1900) combats this view at length with arguments based on the obliquity of the orifice of the blowhole, which is in the form of a slit, and on the inclination of the protuberance of the blowhole. I am of the opinion of Rawitz, but for a reason which seems to me better than his, because it is unanswerable. We have seen above that the blowhole of the whalebone whales is drawn out during the spout into a

conical projection, which does not present the least depression in which water could accumulate.

Other authors have attributed the origin of the little drops of water to that which penetrates into the tube of the blowhole. I do not see any impossibility in this in principle, but would simply remark that the seals and penguins that I have observed close at hand never exhibited this phenomenon. I do not see why the nostrils of the cetaceans should be less well organized than the nostrils of these animals. I hardly need say that this last explanation is merely an hypothesis which is not based on direct observation.

The belief of earlier authors that the whales spout water is certainly based on defective observations and on the blind credence which was accorded to all the stories of Aristotle and Pliny. It seems to me that it is not the same as regards modern authors. I believe that with a part of these at least the influence of an a priori idea has been determinative. To explain the visibility of the spout of the large whales in the polar regions is an easy matter. It is only necessary to show that it is common to all the mammals which are found in those regions and that the phenomenon is observed in winter even in temperate regions. The condensation of water vapor contained in a state of saturation in the warm expired air produces a "cloud" (buée) upon contact with the cold air. It is then natural to associate the spout of a whale with a normal "cloud," only that it is larger, on account of the size of the animal.

This explanation will not suffice, however, in the case of cetaceans whose spout is visible even in high temperatures. It is well known that the sperm whale is found in the tropical seas, where the temperature of the air is often 30° C., and yet the spout of these animals, although less considerable than that of the large polar whales, is, nevertheless, perfectly visible. It is this difficulty of explaining the visibility of the spout of the large whales in high atmospheric temperatures which has led some authors to affirm that the spout is liquid.

There is also another difficulty which presents itself when one attempts to go to the root of the matter. It may be asked why the spout is not visible among the smaller whales if it is a simple "cloud" (buée).

Rawitz (1900) seeks the explanation of the visibility of the spout in tropical regions in the high temperature which the cetaceans are said to possess. He says on page 94: "The temperature of the blood of the large whalebone whales—I believe Kükenthal or Guldberg has made the observation—surpasses the highest fever temperature of man." But this reference is altogether erroneous. It was Guldberg (1900) who published the work to which Rawitz referred, and from this memoir it appears very evident that the temperature of the cetaceans

is inferior to the normal temperature of man. Indeed, muscular or rectal temperatures have quite indisputably given 35.4° C. for *Balænoptera musculus* Comp. (common finback), according to Guldberg, and 35.6° C. for *Delphinus delphis* Cuvier (common dolphin), according to Richard and Neuville, and the temperature of the liver (the warmest organ of the body) 37.8° C. in *Phocæna communis* (harbor porpoise), according to Davy. Guldberg states on page 69: "We may therefore regard a temperature of from 36° to 37° C. as the normal temperature of the cetaceans rather than 38° to 39° C." He means the temperature of the liver, which is certainly higher than that of the lungs and of the air which is contained in them.

If, therefore, the temperature of the cetaceans is sensibly inferior to that of man, it is much lower than that of the majority of land mammals, which have a temperature varying around 39° C. This agrees perfectly with what I have found for the seals and penguins (Racovitza, 1900, p. 206), animals in all points comparable from a physiological point of view.

I would therefore place in opposition to the assertions of Rawitz this general law: The temperature of mammals and birds modified for an aquatic life, in which the body is surrounded by an insulating layer of fat, is inferior to the temperature of their terrestrial allies. These aquatic animals do not produce more heat wherewith to counteract the cold of the medium which they inhabit, but they lose less. The fat which envelopes them prevents the loss of heat to such an extent that a seal which has been dead for twenty-four hours and exposed to a temperature of −20° C. has the viscera still warm (Racovitza, 1900, p. 207), and a *Balænoptera sibbaldi* (sulphurbottom) three days after its death gave 34° C. in the muscles and the blood (Guldberg, 1900).

I would remark here that the fat in cetaceans, seals, and penguins is not reserve matter, as in terrestrial mammals, but a veritable organ of defense against cold, and I shall support with proofs, in a memoir which I have in preparation on seals and penguins, this opinion, which seems a veritable paradox—that aquatic animals which have been almost exterminated on account of their fat are lean animals.

The explanation given by Rawitz is, therefore, at fault, and, furthermore, if it were true it would not explain why the spout of the small cetaceans is not visible, since the difference between the temperature of their body and the external temperature in the intertropical regions would be sufficient, according to his hypothesis, to produce condensation.

My friend, Doctor Portier, chief of physiological investigations at the Sorbonne, has suggested an explanation which seems to me a good one. The effects of confining gases are known by well-established physical experiments. All gases under pressure which are suddenly liberated undergo an instantaneous reduction of tempera-

ture, and it is certain that the phenomenon of the expiration of cetaceans can be compared from every point of view with the phenomena presented by gases under constraint. There is, in effect, a vast pulmonary reservoir inclosed in a powerful thoracic cage, communicating with the exterior by an orifice much reduced in comparison with the capacity of the lungs, and this orifice is opened suddenly at the moment of expiration. The proof that the air is expelled under strong pressure is that the spout rises to a very great height and especially that its emission produces a harsh sound, so characteristic that all authors have compared it to the escape of steam under pressure.

This idea of Portier's seems to me to explain admirably all the peculiarities of the spout: thus, the spout of the small whales is not seen because their muscular power is feeble and the air escapes under a minimum pressure. The expiration which follows the first appearance of the whale after sounding is more forceful than the others, because the animal at the moment of diving has expanded its lungs more strongly than for ordinary immersions and consequently the air is under a more considerable pressure.

I do not wish to maintain that the refrigeration consequent upon the phenomenon of restraint is the sole reason of the visibility of the spout. It is necessary to make a distinction. In the Tropics it is certain that the condensation of the vapor is due solely to refrigeration caused by restraint, but in the polar regions the phenomenon of the buée complicates the causes of this appearance.

6. *Odor of the spout.*—As I have already remarked in another place (p. 632), the odor of the spout of the humpback is nauseating, and confirmation of this observation will be found in Baer (1864), Lilljeborg (1866), Jouan (1882), and other authors whom it is unnecessary to cite here. Jouan (1882, p. 12) remarks, indeed, that this is observed especially among the large species of cetaceans, and that the spout of the sperm whale is particularly fetid, as it provokes nausea and "produces the effect of a blister on the skin." I leave to this author the entire responsibility of this last assertion, and would recall simply that the fetidness of the spout is habitual in the large whales and is not peculiar to the humpbacks.

I have attributed this bad odor somewhat rashly to the bodies of the animals which have decomposed in the whalebone of the baleen whales, a fact often observed. Fishes found in the mouth of *Balænoptera physalus* (common finback) in process of decomposition have been cited, but in addition to the fact that this hypothesis can not be applied to the sperm whale, which is without whalebone, it is also incompatible with the arrangement of the respiratory canal, which is completely isolated from the cavity of the mouth. It is necessary, therefore, to look for the source of infection in the respiratory apparatus itself.

B.—INSPIRATION.

Inspiration is effected immediately after expiration, without an interval. The protuberance of the blowhole is always the only part which appears at the moment on the surface, but its form is now quite different. The orifice in the whalebone whales, instead of being situated on the conical eminence as it is during expiration, is now wide open and the protuberance of the blowhole is so much flattened as to be confounded with the regular contours of the head. This disposition is very clearly shown in the photographs [not here reproduced]. In the toothed whales the modification is less, but the orifice of the blowhole must be wider open than during expiration.

The duration of the inspiration is always less than that of expiration, which can be readily understood. During expiration the orifice of the blowhole is small, and the air, though projected, it is true, with violence, is expelled in a column of small diameter. During the inspiration, on the contrary, the orifice is wide open that the air may be taken in suddenly. The whale has probably acquired this faculty of very rapid inspiration in order that it may be exposed for a less time to the penetration of water into the respiratory apparatus.

I have been able frequently to confirm this extreme rapidity of inspiration in the finbacks, the humpbacks, and the porpoises, and many accurate writers have noted it as well as myself. Thiercelin (1866, vol. 1) states that among all the cetaceans "the expiration is very much longer than the inspiration," and again, "but in all cases, as soon as this operation has ceased, the blowhole appears to sink so much that it is necessary to know that the animal needed to inspire in order not to suppose that it confined itself to the first phase of its function [of breathing]." Henking (1901) has observed among the sulphurbottoms (*B. musculus*) that "the inspiration plainly follows [the expiration] with extraordinary rapidity, and the sounding of the whale occurs very quickly after the projection of the spout." Beale (1839) says that immediately after the sperm whale has blown the inspiration takes place very quickly, because the snout descends. Kükenthal (1903) also maintains from theoretical considerations, on which I do not wish to insist, that the inspiration must be very short.

But Rawitz (1900, a) compels us to give attention anew to his statements. He asserts that the inspiration is longer than the expiration and deeper. On what does this author rely as the basis for this statement? It can only be his own observations, but one can convince oneself as regards their accuracy by running over the lines I have devoted to the humpback. And what is the meaning of an inspiration deeper than an expiration? Does Rawitz imagine that, everything considered, the whale introduces a larger volume of air into its lungs than it rejects? He denies also the enlargement of the

orifice of the blowhole during inspiration, a negation more unfortunate as the fact is undeniable, and he accompanies this opinion with an argument which can not be admitted. He says, in effect, that this enlargement of the blowhole can not serve to accelerate the inspiration in any considerable degree since the nostrils remain always very narrow compared with the quantity of air inspired. Thus, according to Rawitz, the difference between the volume of air which can be taken in by a narrow orifice and that taken in by an orifice ten times as wide is inconsiderable! I leave to him the responsibility for such a conclusion.

The entrance of the air into the lungs of the large cetaceans as well as the expirations produces a certain sound, which is not a "voice," but simply a sound produced by the strongly inspired air passing through the relatively narrow orifice. Sometimes, however, the noise is more harsh, resembling a dull whistle, and with proper allowance it resembles that produced sometimes in the nasal canals of terrestrial animals which are clogged with mucus or any foreign matter.

It is unnecessary to say that the cetaceans breathe air alone, and that they are as much inconvenienced as any land animals when the water penetrates into their respiratory organs.

C.—THE INTERMEDIATE IMMERSIONS.

When a cetacean has respired, as seen above, it dives, executing a rotating movement indicated by the curvature of the body more or less extended, and thereupon continues to advance under water. There is seen, then, at the surface after respiration, which has been indicated by the presence of the protuberance of the blowhole, the slight concavity which marks the rudimentary neck in these animals, then the back always convex for a distance approaching the posterior extremity more or less, according to the species. Thus the right whales show a large part of the back, extending posteriorly beyond the point where the dorsal fin is located in those cetaceans which possess this part. In the humpback the back is also shown to a point behind the dorsal fin. In the finback the dorsal fin is not shown, but the sperm whale shows its dorsal hump and the porpoises their dorsal fins.

The immersion of the animal proceeds from in front backward, always in a curved line, and the cetacean disappears without having shown its tail in any case.

The period of disappearance is longer or shorter, according to the species, but never exceeds a few minutes. Then the protuberance of the blowhole reappears, the whale respires, shows its back, and disappears again. The number of these intermediate immersions before sounding varies according to the species. In general, the whalebone whales execute but few, the toothed whales very many. In all cetaceans, however, they are characterized by the following: (1) The

expiration and inspiration, respectively, are shorter than the first expiration after sounding and the last inspiration before sounding, and these respiratory acts are less deep; (2) the interval between reappearances is very short; (3) the animal dives only to a slight depth, a few meters at most, and generally it keeps immediately below the surface; (4) the posterior part of the body is always invisible; (5) the whale during the time it remains under water progresses quite rapidly, usually in a straight line, but sometimes in a circle when in a narrow bay where space is limited.

The object of these movements is easy to understand. The cetacean does what all diving animals do. Before plunging, for a very long time, it makes many rapid respirations, which permit it to reoxygenate its blood, which has become more or less carbonated since the last sounding; it also permits the animal to surcharge its blood with oxygen for the succeeding immersion. It follows that the cetaceans which make the greatest number of ordinary inspirations before sounding are those which should be able to dive deepest, or at least those which should be able to remain longest under water. In this regard it is the sperm whale which appears to hold the record, for its divings intermediate between soundings are very numerous—60 or 70, says Beale (1839)—and it is also the whale which remains submerged longest, an hour and ten minutes to an hour and twenty minutes, or rarely an hour in the case of large males. The long submersion should be very important for this whale to enable it to procure its food, which consists of large cuttle-fish, animals living at a great depth, the pursuit of which must be long and arduous.

The habits of the bottle-nosed whales (*Hyperoödon*) are similar to those of the sperm whale, and the number of immersions intermediate between two soundings is very large among them also, as will be seen later.

D.—SOUNDING.

When the animal has its store of oxygen, it makes a very deep inspiration in order to carry with it as large a quantity of air as possible. In this also, the cetaceans are not exceptional, but follow the course of all diving animals. The back of the whale is shown immediately, much higher above the surface than in intermediate immersions. The curve formed by the dorsal line is very convex, the rotating movement more pronounced, and the back disappears from the anterior part to the posterior part. What follows is characteristic for each species. The right whales, the humpbacks, and the sperm whales show their flukes above water; at this time the head is directed downward and the axis of the body obliquely. The flukes are waved in the air two or three times and the animal disappears. The finbacks do not show their flukes, but describe a strong curve

approaching a circle. The porpoises jump out of the water and describe an elongated curve in the air, descending head foremost, with the body extended.

The whale dives at once obliquely and disappears for a time longer or shorter, according to the species, but rarely for less than a quarter of an hour. It reappears and spouts very powerfully and long.

The sounding is characterized, then, among all cetaceans by the following peculiarities (1) It commences with an inspiration deeper than any other, and ends with an expiration which is also very strong; (2) the posterior part of the body executes special movements; (3) the whale dives to a great depth; (4) it remains there very long before it appears again.

E.—THE TRACK.

Every time a large whale disappears below the surface, it leaves behind it a slick (grasseur), which is especially plain when the water is but little agitated. This "slick" is unquestionably an extremely thin layer of oil, which spreads on the surface of the water and gives it the well-known mirror-like appearance. This fact has been observed and recorded many times already, and there can be no doubt as to its interpretation.

It is difficult, however, to understand the origin of this oily substance which the whale leaves behind, for anatomists who have studied the skin of the cetaceans (Delage, 1885; Kükenthal, 1889; Rawitz, 1899, among others) have proved the complete absence of sweat glands or sebaceous glands. The oil can not, then, be derived from secretions of the skin. Inthe common dolphin, a species which I have examined in this particular, the skin is entirely without a trace of oil; it is perfectly dry and does not leave any mark on a well-cleaned glass. It follows, therefore, that this oil must have some other origin. The following observations may, perhaps, put us on the track of the truth. Thiercelin (1866, vol. 1) says regarding the southern right whale: "Some little drops of oily matter drop from the spout." If this observation is verified—for it can not be admitted without hesitation—it gives us the source of the "slick" mentioned; but another observation which I made in Gerlache Strait appears to me to supply a more plausible explanation. I noticed at the surface of the water, among the finbacks and humpbacks of the strait, some irregular masses of a red color surrounded by "slicks." They were without doubt the excrements of these animals. The seals and penguins had similar excrements, the color of which is explained by the fact that the food of these animals consists of *Euphausia* (a small thysanopod crustacean), which is abundantly provided with red pigment. The *Euphausia*, like all planctonic animals, possesses numerous small globules of oil in its tissues, which must serve as floats in animals which pass their lives in

the water. This being so, the waste products of digestion of the mammals and birds which feed upon them must contain oil. It is therefore possible that the large whales excrete small quantities of oily matter, which may be the origin of the "slicks" observed.

Various movements executed by cetaceans.

The movements thus far analyzed are the habitual movements, and, so to speak, permanent in the normal life of the whales, but there are others which these animals execute under certain conditions which are special, or exceptional in their lives, and which we must now analyze.

A. Leaps and gambols.—These movements are observed among many cetaceans, but especially among certain species, in connection with which they constitute a genuine specific character. The humpback is especially prone to leaping out of water, which will be described in detail in a subsequent chapter. The finbacks do not appear to indulge in these gambols, but they enter into the habits of the sperm whale (Beale, 1839). American and English whalers have coined a word to designate the action of leaping out of water among large whales. They call it "breaching." The small porpoises spring out of water and are known to follow vessels under way and to outstrip them in speed. Large finbacks are also mentioned which have followed boats for a very long time (Rodler, 1888).

B. Resting on the surface.—Right whales and humpbacks have the habit of remaining motionless at the surface of the water. The whalers pretend that it is for the purpose of sleeping, but this assertion needs to be confirmed.

It appears from the published observations that this resting on the water is but rarely observed. I only saw it once during three seasons which I passed in Gerlache Strait, when our vessel was constantly surrounded by humpbacks. It has never been observed with certainty among the finbacks or porpoises. This seems to me to indicate that it can not be interpreted as a function so normal and periodic as sleep.

But it properly may be asked whether whales sleep at all. I am inclined to answer this question negatively. During our sojourn in Gerlache Strait and among the icebergs we heard the whales blow at all hours of day and night, confirming Jouan's observation of 1882. I often observed porpoises following the boats at night, while on the other hand, *Delphinus delphis* L. (common dolphin) caused havoc in the fishing apparatus used for taking anchovies and sardines at all times and at all hours of the day and night.

Rodler (1888, p. 274) reports that a steamer was followed by the same school of cetaceans from Cape Horn to Liverpool, and Moseley (1892, p. 9) declares that a humpback (*Megaptera*) followed the *Challenger* many days. During these voyages the whales must have swum

actively, which excludes the possibility of sleep, even if we admit that the necessary movements of respiration could be automically performed, as Jouan supposes (1882), for it is not possible to maintain that the whales could follow automatically a ship the course of which is variable.

It is possible to form three hypotheses regarding the sleep of whales. One can suppose, first, that they sleep at the bottom of the sea. Buchet (1895) is of this opinion, and believes what the fishermen told him on this subject, for he says: "They [the whales] often emerged suddenly all around the ship without having been seen at a distance." This applies to the heavy whales and the porpoises which would sleep at night. The fact which Buchet reports as a proof of the correctness of his opinion is explained in quite another manner. It is not a matter for astonishment to see animals suddenly appear, which swim as much as 12 miles an hour (Scoresby, 1820) and can remain under water more than half an hour.

The opinion of Buchet can not be accepted for many reasons. Cetaceans could sleep but poorly at the bottom of the sea, since they are obliged to ascend to breathe. When they inhabit deep seas they could not sleep, for the cetaceans do not dive to a great depth. Their skin is so delicate that the contact with the bottom would be injurious to them. I do not believe, therefore, that this first hypothesis can be maintained.

I will note here merely for reference a curious work of Barkow (1862) which is connected with the hypothesis which I am about to examine and which contains the following conclusions: "The summer life of the whalebone whales is preëminently the life of the mammals depending on atmospheric lungs; their winter life preëminently a submarine life, depending on the abdominal vessels (Darmgefässleben)." This author therefore considers the cetaceans as hibernating animals, which pass a part of their existence at the bottom of the sea. He reaches this strange deduction as a result of erroneous conclusions, regarding which I will not enter into details here.

The second hypothesis that can be put forward is also improbable, namely, that the cetaceans sleep at the surface. It is well known, indeed, that the cetaceans, which are heavier than the water, could not maintain themselves at the surface except by swimming. The genus *Balæna* makes the single exception—the right whales float, but they float on the back (which is very much heavier than the belly) if they do not maintain themselves actively in the natural position. This brings matters to the same point as in the case of the heavy cetaceans—in the one instance as in the other the blowhole would be below the surface.

The third hypothesis is much more plausible. In sleeping whales execute automatically the movements necessary to respiration. It is well known that horses in harness can sleep perfectly well while pull-

ing a wagon, and that even a man can sleep while marching. There is nothing, therefore, which, a priori, could prevent our accepting this hypothesis, but we have seen that the observations cited at the beginning of this paragraph tend rather to cause us to hold that the cetaceans do not sleep at all. If I dwell on this subject, it is merely to show its interest and the small amount of data we possess for the solution of the problem.

C. Migrations.—Cetaceans have often been seen in the open sea, traveling straight ahead, without sounding; in these cases they are following a course in search of a new feeding place, or perhaps for the needs of reproduction.

CONCLUSIONS RELATIVE TO MOVEMENTS.

From this brief inquiry relative to the movements of cetaceans, it results that these movements vary according to the species. It is this point which seems to me especially important from a practical point of view, and in the chapters which follow I shall demonstrate, with suitable proofs, that it is certainly so, for the species I have been able to study. I lay down the principle, therefore, that the movements of cetaceans in the water are specific. In combining the results derived from observation of movements, with data supplied by dimensions, form, and color, one becomes able to recognize readily every kind of whale with as much certainty as if one had the animal at one's disposal to dissect—an opportunity which presents itself but rarely.

THE DEPTH TO WHICH CETACEANS DIVE.

I will pass in closing this chapter to the consideration of a fundamental question in the biology of the Cetacea—the depth to which they dive. There are no direct observations for the solution of this problem and those cetologists who mention it incidentally content themselves with assertions without proofs. All give very high figures, and Kükenthal (1900, p. 197) pretends even that cetaceans can dive more than 1,000 meters (3,281 feet), but without mentioning on what he bases this assertion. I do not believe that this depth can ever be attained by these animals; on the contrary, I believe that they can not exceed a maximum depth of 100 meters (328 feet). Let us examine into what takes place when a cetacean dives.

First.—The pressure of the water: It is necessary not to forget that the cetaceans have an aërial respiration—that their pulmonary cavities are filled with air. On the other hand, we know what takes place when a mammal is submitted to a pressure of several atmospheres; the gases dissolve in large quantities in the blood, and when the pressure is relieved suddenly the surplus of dissolved gas can not be eliminated by the lungs; the gaseous bubbles form in the capillaries, which arrest the circulation of the blood and cause death. For man, the

limit of depth to which he can venture without danger is 30 meters (98 feet)—that is to say, the pressure of three atmospheres. No mammal confined under nine atmospheres and suddenly released has survived this treatment; therefore, 90 meters (295 feet) is a limit which no terrestrial mammal can reach. It may be admitted, however, that the whale is accustomed little by little to depths more and more considerable, and in his case to increase the depth he can reach, but it is not possible to believe that he can annihilate entirely the physical law of solution of gases in liquids proportional to pressure, nor that he can prevent the disengagement of these gases when the pressure ceases. Therefore, in giving to the cetaceans, in view of this supposed adaptation, a power three times as great as that of the human organism, we must be close to the truth. I believe, indeed, that this limit of 100 meters which I have assigned to the cetaceans is rather exaggerated.

Second.—The weight: The density of the body of the cetaceans is less than that of the sea water in the right whale and the sperm whale; it is a very little superior in the other cetaceans, which sink when killed. To go down, therefore, it is necessary that the whale should swim to the bottom. Furthermore, the living cetacean carries an enormous quantity of air in its lungs, which tends to make it rise to the surface.

That being so, one can imagine the effort required of a cetacean to plunge to 1,000 meters. It is an effort so enormous that it certainly surpasses the animal's muscular power. One should not forget that a man, whose body is much denser than that of a whale, has to load himself with a very considerable weight when he wishes to dive into the sea to depths which exceed a few meters. I recall that the costume of a diver weighs 80 kilograms. This is another consideration which prevents me from believing in the 1,000 meters of Kükenthal.

Third.—Light: We know that the light of day does not penetrate deeper than 300 meters (984 feet) and that, furthermore, at this depth only the chemical rays of the spectrum make their effect felt. One may say, indeed, that practically, for the eye of a mammal, the illuminated zone does not pass 50 or 60 meters. If sight is unnecessary to the cetaceans which feed upon the plancton, it must, on the contrary, be indispensable to those which feed on fish and cephalopod mollusks. What would they do, then, in the depths beyond the limit of illumination that can be utilized?

Fourth.—Food: Whales do not dive for pleasure, they dive in search of food. But what could they find at 1,000 meters? The fishes on the banks scarcely inhabit great depths, and the zone where the plancton is very abundant—that in which the crustaceans live which serve as food is the zone of the diatoms, that is, the illuminated zone—extends to about 100 meters. That there is plancton below this zone is not

doubtful, but why should the cetacean dive down there if it finds what it needs with less exertion?

Fifth.—The fishing ground: The cetaceans seek in general the proximity of the coasts, and very often they are seen preferably in places of little depth. In these places they execute their movements as usual; they remain under water as long as when in the open sea, and if they remain there so long it is not in order to have time to reach great depths, as has been said, but simply because they require this time to procure food.

These, then, are the considerations which cause me to reject entirely the ideas of those who believe that the cetaceans can dive to great depths. I believe, on the contrary, that the cetaceans dive some dozens of meters, and 100 meters seems to me a limit which can hardly be exceeded.

The only direct observation that I have been able to find which is worthy of confidence confirms this opinion. The Japanese take whales in nets, and in a book on the whale fishery, dating from 1829 (Möbius, 1893), I find the following passage: "Whales which dive deeper than 18 hiro (27.4 meters) can not be taken in nets except where the bottom does not exceed this depth, but as the *Semikoujira* (*Balæna japonica*, right whale of Japan) does not dive below this depth it can be captured in nets at all depths."

We see, then, that the right whale does not dive below 28 meters. The right whale is the one whose density is the least, so that when dead it floats; the others dive below 28 meters, but does anyone suppose that the difference can be so great between animals so closely related, having the same habits and the same structure, as to permit that one can not exceed 28 meters while the other can exceed 1,000 meters?

PROBLEMS ARISING FROM VARIATIONS IN THE DEVELOPMENT OF SKULL AND BRAINS.[a]

By Prof. Johnson Symington, M. D., F. R. S., F. R. S. E.

It is now nearly twenty years since anthropology attained to the dignity of being awarded a special and independent section in this association, and I believe it is generally admitted that during this period the valuable nature of many of the contributions, the vigor of the discussions, and the large attendance of members have amply justified the establishment and continued existence of this section.

While the multifarious and diverse nature of the subjects which are grouped under the term anthropology gives a variety and a breadth to our proceedings which are very refreshing in this age of minute specialism, I feel that it adds very considerably to the difficulty of selecting a subject for a presidential address which will prove of general interest.

A survey of the recent advances in our knowledge of the many important questions which come within the scope of this section would cover too wide a field for the time at my disposal, while a critical examination of the various problems that still await solution might expose me to the temptation of pronouncing opinions on subjects regarding which I could not speak with any real knowledge or experience. To avoid such risks I have decided to limit my remarks to a subject which comes within the range of my own special studies, and to invite your attention to a consideration of some problems arising from the variations in the development of the skull and the brain.

Since the institution of this section the development, growth, and racial peculiarities of both skull and brain, and the relation of these two organs to each other, have attracted an ever-increasing amount of attention. The introduction of new and improved methods for the study of the structure of the brain and the activity of an able band of experimentalists have revolutionized our knowledge of the anatomy and physiology of the higher nerve centers.

The value of the results thus obtained is greatly enhanced by the consciousness that they bear the promise of still greater advances in

[a] Address by the president to the anthropological section of the British Association at the Southport meeting, 1903. Reprinted from Report of the British Association for the Advancement of Science, 1903.

the near future. If the results obtained by the craniologist have been less marked, this arises mainly from the nature of the subject, and is certainly not due to any lack of energy on their part. Our craniological collections are continually increasing, and the various prehistoric skullcaps from the Neanderthal to the Trinil still form the basis of interesting and valuable memoirs.

While the additions to our general knowledge of cerebral anatomy and physiology have been so striking, those aspects of these subjects which are of special anthropological interest have made comparatively slight progress and can not compare in extent and importance with the advantages based upon a study of fossil and recent crania. These facts admit of a ready explanation. Brains of anthropological interest are usually difficult to procure and to keep, and require the use of special and complicated methods for their satisfactory examination, while skulls of the leading races of mankind are readily collected, preserved, and studied. Hence it follows that the crania in our anthropological collections are as numerous, well preserved, and varied as the brains are few in number and defective, both in their state of preservation and representative character. It may reasonably be anticipated that improved methods of preservation and the growing recognition on the part of anthropologists, museum curators, and collectors of the importance of a study of the brain itself will, to some extent at least, remedy these defects; but so far as prehistoric man is concerned we can never hope to have any direct evidence of the condition of his higher nerve centers, and must depend for an estimate of his cerebral development upon those more or less perfect skulls which fortunately have resisted for so many ages the corroding hand of time.

I presume we will all admit that the main value of a good collection of human skulls depends upon the light which they can be made to throw upon the relative development of the brains of different races. Such collections possess few if any brains taken from these or corresponding skulls, and we are thus dependent upon the study of the skulls alone for an estimate of brain development.

Vigorous attacks have not unfrequently been made upon the craniometric systems at present in general use, and the elaborate tables, compiled with so much trouble, giving the circumference, diameters, and corresponding indexes of various parts of the skull, are held to afford but little information as to the real nature of skull variations, however useful they may be for purposes of classification. While by no means prepared to express entire agreement with these critics, I must admit that craniologists as a whole have concentrated their attention mainly on the external contour of the skull, and have paid comparatively little attention to the form of the cranial cavity. The outer surface of the cranium presents features which are due to other factors than brain development, and an examination of the cranial cavity not

only gives us important information as to brain form, but by affording a comparison between the external and internal surfaces of the cranial wall it gives a valuable clew to the real significance of the external configuration. Beyond determining its capacity we can do but little toward an exact investigation of the cranial cavity without making a section of the skull. Forty years ago Professor Huxley, in his work On the Evidence of Man's Place in Nature, showed the importance of a comparison of the basal with the vaulted portion of the skull, and maintained that until it should become "an opprobrium to an ethnological collection to possess a single skull which is not bisected longitudinally" there would be "no safe basis for that ethnological craniology which aspires to give the anatomical characters of the crania of the different races of mankind." Professor Cleland and Sir William Turner have also insisted upon this method of examination, and only two years ago Prof. D. J. Cunningham, in his presidential address to this section, quoted with approval the forcible language of Huxley. The curators of craniological collections appear, however, to possess an invincible objection to any such treatment of the specimens under their care. Even in the Hunterian Museum in London, where Huxley himself worked at this subject, among several thousands of skulls, scarcely any have been bisected longitudinally or had the cranial cavity exposed by a section in any other direction. The method advocated so strongly by Huxley is not only essential to a thorough study of the relations of basi-cranial axis to the vault of the cranium and to the facial portion of the skull, but also permits of casts being taken of the cranial cavity, a procedure which, I would venture to suggest, has been too much neglected by craniologists.

Every student of anatomy is familiar with the finger-like depressions on the inner surface of the cranial wall, which are described as the impress of the cerebral convolutions; but their exact distribution and the degree to which they are developed according to age, sex, race, etc., still remain to be definitely determined. Indeed, there appears to be a considerable difference of opinion as to the degree of approximation of the outer surface of the brain to the inner surface of the cranial wall. Thus the brain is frequently described as lying upon a water bed, or as swimming in the cerebro-spinal fluid, while Hyrtle speaks of this fluid as a "ligamentum suspensorium" for the brain. Such descriptions are misleading when applied to the relation of the cerebral convolutions to the skull. There are, it is true, certain parts of the brain which are surrounded and separated from the skull by a considerable amount of fluid. These, however, are mainly the lower portions, such as the medu la oblongata and pons Varolii, which may be regarded as prolongations of the spinal cord into the cranial cavity. As they contain the centers controlling the action of the circulatory and respiratory organs, they are the most vital parts of the central

nervous system, and hence need special protection. They are not, however, concerned with the regulation of complicated voluntary movements, the reception and storage of sensory impressions from lower centers, and the activity of the various mental processes. These functions we must associate with the higher parts of the brain, and especially with the convolutions of the cerebral hemispheres.

If a cast be taken of the cranial cavity and compared with the brain which had previously been carefully hardened in situ before removal, it will be found that the cast not only corresponds in its general form to that of the brain, but shows a considerable number of the cerebral fissures and convolutions. This molding of the inner surface of the skull to the adjacent portions of the cerebral hemispheres is usually much more marked at the base and sides than over the vault. Since the specific gravity of the brain tissue is higher than that of the cerebro-spinal fluid, the cerebrum tends to sink toward the base and the fluid to accumulate over the vault; hence probably these differences admit of a simple mechanical explanation. Except under abnormal conditions, the amount of cerebro-spinal fluid between the skull and the cerebral convolutions is so small that from a cast of the cranial cavity we can obtain not only a good picture of the general shape and size of the higher parts of the brain, but also various details as to the convolutionary pattern. This method has been applied with marked success to the determination of the characters of the brain in various fossil lemurs by Dr. Forsyth Major and Prof. R. Burckhardt, and Prof. Gustav Schwalbe has made a large series of such casts from his craniological collection in Strassburg. The interesting observations by Schwalbe[a] on the arrangement of the "impressiones digitatæ" and "juga cerebralia," and their relation to the cerebral convolutions in man, the apes, and various other mammals, have directed special attention to a very interesting field of inquiry. As is well known, the marked prominence at the base of the human skull, separating the anterior from the middle fossa, fits into the deep cleft between the frontal and temporal lobes of the brain, and Schwalbe has shown that this ridge is continued—of course in a much less marked form—along the inner surface of the lateral wall of the skull, so that a cast of the cranial cavity presents a shallow but easily recognized groove corresponding to the portion of the Sylvian fissure of the brain separating the frontal and parietal lobes from the temporal lobe. Further, there is a distinct depression for the lodgment of the inferior frontal convolution, and a cast of the middle cranial fossa shows the three external temporal convolutions.

We must now turn to the consideration of the relations of the outer surface of the cranium to its inner surface and to the brain. This

[a] Über die Beziehungen zwischen Innenform und Aussenform des Schädels, Deutsches Archiv für klinische Medicin, 1902.

question has engaged the attention of experts as well as the "man in the street" since the time of Gall and Spurzheim, and one might naturally suppose that the last word had been said on the subject. This, however, is far from being the case. All anatomists are agreed that the essential function of the cranium is to form a box for the support and protection of the brain, and it is generally conceded that during the processes of development and growth the form of the cranium is modified in response to the stimulus transmitted to it by the brain. In fact, it is brain growth that determines the form of the cranium, and not the skull that molds the brain into shape. This belief, however, need not be accepted without some reservations. Even the brain may be conceived as being influenced by its immediate environment. There are probably periods of development when the form of the brain is modified by the resistance offered by its coverings, and there are certainly stages when the brain does not fully occupy the cranial cavity.

At an early period in the phylogeny of the vertebrate skull the structure of the greater part of the cranial wall changes from membranous tissue into cartilage, the portion persisting as membrane being situated near the median dorsal line. In the higher vertebrates the rapid and early expansion of the dorsal part of the forebrain is so marked that the cartilaginous growth fails to keep pace with it, and more and more of the dorsal wall of the cranium remains membranous, and subsequently ossifies to form membrane bones. Cartilage, though constituting a firmer support to the brain than membrane, does not possess the same capacity of rapid growth and expansion. The head of a young child is relatively large, and its skull is distinguished from that of an adult by the small size of the cartilaginous base of the cranium as compared with the membranous vault. The appearance of topheaviness in the young skull is gradually obliterated as age advances by the cartilage continuing slowly to grow after the vault has practically ceased to enlarge. These changes in the shape of the cranium are associated with corresponding alterations in that of the brain, and it appears to me that we have here an illustration of how the conditions of skull growth may modify the general form of the brain.

Whatever may be the precise influences that determine skull and brain growth, there can be no doubt but that within certain limits the external form of the cranium serves as a reliable guide to the shape of the brain. Statements such as those by Dr. J. Deniker,[a] "that the inequalities of the external table of the cranial walls have no relation whatever with the irregularities of the inner table, and still less have anything in common with the configuration of the various parts of the brain," are of too general and sweeping a character. Indeed, various observers have drawn attention to the fact that in certain regions the

[a] The Races of Man, p. 53.

outer surface of the skull possesses elevations and depressions which closely correspond to definite fissures and convolutions of the brain. Many years ago Sir William Turner, who was a pioneer in cranio-cerebral topography, found that the prominence on the outer surface of the parietal bone, known to anatomists as the parietal eminence, was situated directly superficial to a convolution of the parietal lobe of the brain, which he consequently very appropriately named "the convolution of the parietal eminence." Quite recently Prof. G. Schwalbe has shown that the position of the third or inferior frontal convolution is indicated by a prominence on the surface of the cranium in the anterior part of the temple. This area of the brain is of special interest to all students of cerebral anatomy and physiology, since it was the discovery by the illustrious French anthropologist and physician, M. Broca, that the left inferior frontal convolution was the center for speech, that laid the scientific foundation of our present knowledge of localization of function in the cerebral cortex. This convolution is well known to be much more highly developed in man than in the anthropoid apes, and the presence of a human cranial speech bump is usually easily demonstrated. The faculty of speech, however, is such a complicated cerebral function that I would warn the "new" phrenologist to be cautious in estimating the loquacity of his friends by the degree of prominence of this part of the skull, more particularly as there are other and more reliable methods of observation by which he can estimate this capacity.

In addition to the prominences on the outer surface of the cranium, corresponding to the convolutions of the parietal eminence and the left inferior frontal convolution, the majority of skulls possess a shallow groove marking the position of the Sylvian point and the course of the horizontal limb of the Sylvian fissure. Below these two other shallow oblique grooves indicate the line of the cerebral fissures which divide the outer surface of the temporal lobe into its three convolutions, termed "superior," "middle," and "inferior." Most of these cranial surface markings are partially obscured in the living body by the temporal muscle, but they are of interest as showing that in certain places there is a close correspondence in form between the external surface of the brain and that of the skull. There are, however, distinct limitations in the degree to which the various cerebral fissures and convolutions impress the inner surface of the cranial wall, or are represented by inequalities on its outer aspect. Thus over the vault of the cranium the position of the fissure of Rolando and the shape of the cerebral convolutions in the so-called motor area, which lie in relation to this fissure, can not usually be detected from a cast of the cranial cavity, and are not indicated by depressions or elevations on the surface of the skull, so that surgeons in planning the seats of operations necessary to expose the various motor centers have

to rely mainly upon certain linear and angular measurements made from points frequently remote from these centers.

The cranium is not merely a box developed for the support and protection of the brain, and more or less accurately molded in conformity with the growth of this organ. Its antero-lateral portions afford attachments to the muscles of mastication and support the jaws and teeth, while its posterior part is liable to vary according to the degree of development of the muscles of the nape of the neck. Next to the brain the most important factor in determining cranial form is the condition of the organs of mastication—muscles, jaws, and teeth. There is strong evidence in favor of the view that the evolution of man from microcephaly to macrocephaly has been associated with the passage from a macrodontic to a microdontic condition. The modifications in the form of the cranium due to the influence of the organs of mastication have been exerted almost entirely upon its external table; hence external measurements of the cranium, as guides to the shape of the cranial cavity and indications of brain development, while fairly reliable in the higher races, become less and less so as we examine the skulls of the lower races, of prehistoric man, and of the anthropoid apes.

One of the most important measurements of the cranium is that which determines the relation between its length and breadth and thus divides skulls into long or short, together with an intermediate group neither distinctly dolichocephalic nor brachycephalic. These measurements are expressed by an index in which the length is taken as 100. If the proportion of breadth to length is 80 or upward, the skull is brachycephalic; if between 75 and 80, mesaticephalic; and below 75, dolichocephalic. Such a measurement is not so simple a matter as it might appear at first sight, and craniologists may themselves be classified into groups according as they have selected the nasion, or depression at the root of the nose, the glabella, or prominence above this depression, and the ophryon, a spot just above this prominence, as the anterior point from which to measure the length. In a young child this measurement would practically be the same whichever of these three points was chosen, and each point would be about the same distance from the brain. With the appearance of the teeth of the second detention and the enlargement of the jaws, the frontal bone in the region of the eyebrows and just above the root of the nose thickens, and its outer table bulges forward so that it is now no longer parallel with the inner table. Between these tables air cavities gradually extend from the nose, forming the frontal sinuses. Although the existence and significance of these spaces and their influence on the prominence of the eyebrows were the subject of a fierce controversy more than half a century ago between the phrenologists and their

opponents, it is only recently that their variations have been carefully investigated.

The frontal sinuses are usually supposed to vary according to the degree of prominence of the glabella and the supraorbital arches. This, however, is not the case. Thus Schwalbe[a] has figured a skull in which the sinuses do not project as high as the top of the glabella and supraorbital prominences, and another in which they extend considerably above these projections. Further, Dr. Logan Turner,[b] who has made an extensive investigation into these cavities, has shown that in the aboriginal Australian, in which this region of the skull is unusually prominent, the frontal sinuses are frequently either absent or rudimentary. The ophryon has been selected by some craniologists as the anterior point from which to measure the length of the skull, under the impression that the frontal sinuses do not usually reach above the glabella. Dr. Logan Turner, however, found that out of 174 skulls in which the frontal sinuses were present, in 130 the sinuses extended above the ophryon. In 71 skulls the depth of the sinus at the level of the ophryon varied from 2 to 16 millimeters, the average being 5.2 millimeters, while in the same series of skulls the depth at the glabella varied from 3 to 18 millimeters, with an average depth of 8.5 millimeters. It thus appears that the selection of the ophryon in preference to the glabella, as giving a more accurate clue to the length of the brain, is based upon erroneous assumptions, and that neither point can be relied upon in the determination of the anterior limit of the cranial cavity.

The difficulties of estimating the extent of the cranial cavity by external measurements and the fallacies that may result from a reliance upon this method are especially marked in the case of the study of the prehistoric human calvaria, such as the Neanderthal and the Trinil and the skulls of the anthropoid apes.

Statistics are popularly supposed to be capable of proving almost anything, and certainly if you allow craniologists to select their own points from which to measure the length and breadth of the cranium they will furnish you with tables of measurements showing that one and the same skull is dolichocephalic, mesaticephalic, and brachycephalic. Let us take as an illustration an extreme case, such as the skull of an adult male gorilla. Its glabella and supraorbital arches will be found to project forward, its zygomatic arches outward, and its transverse occipital crests backward far beyond the anterior, lateral, and posterior limits of the cranial cavity. These outgrowths are obviously correlated with the enormous development of the muscles of mastication and those of the back of the neck. In a specimen

[a] "Studien über Pithecanthropus erectus," Zeitschrift für Morphologie und Anthropologie, Bd. i., 1899.

[b] The Accessory Sinuses of the Nose, 1901.

in my possession the greatest length of the cranium, i. e., from glabella to external occipital protuberance, is 195 millimeters, and the greatest breadth, taken between the outer surfaces of the zygomatic processes of the temporal bone, is 172 millimeters, giving the marked brachycephalic index of 88.21. The zygomatic processes, however, may reasonably be objected to as indicating the true breadth, and the side wall of the cranium just above the line where the root of this process springs from the squamous portion of the temporal bone will certainly be much nearer the cranial cavity. Measured in this situation the breadth of the cranium is 118 millimeters, which gives a length-breadth index of 60.51, and thus represents the skull as decidedly dolichocephalic. The transverse occipital crests and the point where these meet in the middle line to form the external occipital protuberance are much more prominent in the male than in the female gorilla, and the estimate of the length of the cranium in this male gorilla may be reduced to 160 millimeters, by selecting the base of the protuberance in place of its posterior extremity as the posterior end measurement. This raises the index to 73.75, and places the skull near the mesaticephalic group. At the anterior part of the skull the prominent glabella is separated from the inner table of the skull by large air sinuses, so that on a median section of the skull the distance from the glabella to the nearest part of the cranial cavity is 36 millimeters. We have here, therefore, another outgrowth of the cranial wall which in an examination of the external surface of the skull obscures the extent of the cranial cavity. Accordingly the glabella can not be selected as the anterior point from which to measure the length of the cranium, and must, like the zygomatic arches and occipital protuberance, be excluded from our calculations if we desire to determine a true length-breadth index. The difficulty, however, is to select a definite point on the surface of the cranium to represent its anterior end, which will be free from the objections justly urged against the glabella. Schwalbe suggests the hinder end of the supraglabellar fossa, which he states often corresponds to the beginning of a more or less distinctly marked frontal crest. I have found this point either difficult to determine or too far back. Thus in my male gorilla the posterior end of this fossa formed by the meeting of the two temporal ridges was 56 millimeters behind the glabella, and only 24 millimeters from the bregma, while in the female gorilla the temporal ridges do not meet, but there is a low median frontal ridge, which may be considered as bounding posteriorly the supraglabellar fossa. This point is 22 millimeters from the glabella, and between 50 and 60 millimeters in front of the bregma.

I would suggest a spot in the median line of the supraglabellar fossa which is crossed by a transverse line uniting the posterior bor-

ders of the external angular processes of the frontal bone. I admit this plan is not free from objections, but it possesses the advantages of being available for both male and female skulls. In my male skull the selection of this point diminishes the length of the cranium by 25 millimeters, thus reducing it to 137 millimeters. The breadth being calculated at 114 millimeters the index is 83.21, and hence distinctly brachycephalic. The length of the cranial cavity is 118 millimeters and the breadth 96 millimeters, and the length-breadth index is thus the brachycephalic one of 81.36.

I have given these somewhat detailed references to the measurements of this gorilla's skull because they show in a very clear and obvious manner that from an external examination of the skull one might easily be misled as to the size and form of the cranial cavity, and that in order to determine from external measurements the proportions of the cranial cavity, skull outgrowths due to other factors than brain growth must be rigorously excluded. Further, these details will serve to emphasize the interesting fact that the gorilla's skull is decidedly brachycephalic. This character is by no means restricted to the gorilla, for it has been clearly proved by Virchow, Schwalbe, and others that all the anthropoid apes are markedly round-headed. Ever since the introduction by the illustrious Swedish anthropologist, Anders Retzius, of a classification of skulls according to the proportions between their length and breadth, great attention has been paid to this peculiarity in different races of mankind. It has been generally held that brachycephaly indicates a higher type of skull than dolichocephaly, and that the increase in size of the brain in the higher races has tended to produce a brachycephalic skull. When the cranial walls are subject to excessive internal pressure, as in hydrocephalus, the skull tends to become distinctly brachycephalic, as a given extent of wall gives a greater internal cavity in a spherical than an oval form. In estimating the value of this theory as to the evolutionary line upon which the skull has traveled, it is obvious that the brachycephalic character of the skulls of all the anthropoid apes is a fact which requires consideration.

Although an adult male gorilla, such as I have selected, presents in an extreme degree outgrowths from the cranial wall masking the true form of the cranial cavity, the same condition, though to a less marked extent, is met with in with the human subject. Further, it is interesting to note that the length of the skull is more liable to be increased by such growths than the breadth, since they occur especially over the lower part of the forehead and to a less degree at the back of the skull, while the side walls of the cranium in the region of its greatest breadth generally remain thin.

Few if any fossils have attracted an equal amount of attention or given rise to such keen controversies as the "Neanderthal" and the

"Trinil" skullcaps. According to some authorities, both these skullcaps are undoubtedly human, while others hold that the "Neanderthal" belongs to an extinct species of the genus Homo, and the "Trinil" is the remains of an extinct genus—*Pithecanthropus erectus* of Dubois—intermediate between man and the anthropoids. One of the most obvious and easily recognized peculiarities of these skullcaps is the very marked prominence of the supraorbital arches. The glabella-occipital length of the Neanderthal is 204 millimeters, and the greatest transverse diameter, which is over the parietal region, is 152 millimeters—an index of 74.51—while the much smaller Trinil calvaria, with a length of 181 millimeters and a breadth of 130 milimeters, has an index of 71.8. Both of these skulls are therefore slightly dolichocephalic. Schwalbe has corrected these figures by making reductions in their lengths on account of the frontal "outworks," so that he estimates the true length-breadth index of the Neanderthal as 80 and that of the Trinil as 75.5. These indices, thus raised about 5 per cent, are considered to represent approximately the length-breadth index of the cranial cavity. A comparison of the external and internal measurements of many recent skulls with prominent glabellæ would, I suspect, show a greater difference than that calculated by Schwalbe for the Neanderthal and Trinil specimens. In a male skull, probably an aboriginal Australian, with a cranial capacity of 1,227 cubic centimeters, I found that the glabella-occipital length was 189 millimeters and the transverse diameter at the parieto-squamous suture 127 millimeters, which gives an index of 67.20 and makes the skull decidedly dolichocephalic. The length of the cranial cavity, however, was 157 millimeters and the breadth 121 millimeters (an index of 77.07 and a difference of nearly 10 per cent), so that while from external measurements the skull is distinctly dolichocephalic, the proportions of its cavity are such that it is mesaticephalic. It is probable that many skulls owe their dolichocephalic reputation simply to the prominence of the glabella and supraorbital ridges. An excessive development of these structures is also liable to give the erroneous impression of a retreating forehead. In the Australian skull just mentioned the thickness of the cranial wall at the glabella was 22 millimeters. From this level upward it gradually thinned, until 45 millimeters above the glabella it was only 6 millimeters thick. When the bisected skull was placed in the horizontal position the anterior surface of the frontal bone sloped from the glabella upward and distinctly backward, while the posterior or cerebral surface was inclined upward and forward. In fact, the cranial cavity in this region was separated from the lower part of the forehead by a wedge-shaped area having its apex upward and its base below at the glabella.

The cranial wall opposite the glabella is not appreciably thicker in the Neanderthal calvaria than in the Australian skull to which I have

already referred, and the form of the cranial cavity is not more masked by this prominence in the Neanderthal than in many of the existing races.

Although the Neanderthal skull is by no means complete, the base of the cranium and the face bones being absent, still those parts of the cranial wall are preserved that are specially related to the portion of the brain which subserves all the higher mental processes. It includes the frontal, parietal, and upper part of the occipital bones, with parts of the roof of the orbits in front, and of the squamous division of the temporal bones at the sides. On its inner or cranial aspect there are markings by which the boundaries between the cerebrum and the cerebellum can be determined. In a profile view of such a specimen an inioglabellar line can be drawn which will correspond very closely to the lower boundary of the cerebrum, and indicate a horizontal plane above which the vaulted portion of the skull must have contained nearly the whole of the cerebrum.

Schwalbe[a] has devised a series of measurements to illustrate what he regards as essential differences between the Neanderthal skullcap and the corresponding portion of the human skull. From the inioglabellar line another is drawn at right angles to the highest part of the vault, and by comparing the length of these two lines we can determine the length-height index. According to Schwalbe, this is 40.4 in the Neanderthal, while the minimum in the human skull is 52. He further shows that the frontal portion of the vault, as represented by a glabella-bregmatic line, forms a smaller angle with the base or inioglabular line, and that a vertical line from the posterior end of the frontal bone (bregma) cuts the inioglabella farther back than in the human subject. Professor King, of Galway, attached special importance to the shape and proportions of the parietal bones, and more particularly to the fact that their mesial borders are shorter than the lower or temporal, whereas the reverse is the case in recent man. This feature is obviously related to the defective expansion of the Neanderthal vault, and Professor Schwalbe also attributes considerable significance to this pecularity.

Another distinctive feature of the Neanderthal skull is the relation of the orbits to the cranial wall. Schwalbe shows that its brain case takes a much smaller share in the formation of the roof of the orbit than it does in recent man, and King pointed out that a line from the anterior inferior angle of the external orbital process of the frontal bone, drawn at right angles to the inioglabellar line, passed in the Neanderthal in front of the cranial cavity, whereas in man such a line would have a considerable portion of the frontal part of the brain case anterior to it.

From the combined results of these and other measurements, Schwalbe arrives at the very important and interesting conclusion that

[a] "Ueber die specifischen Merkmale des Neanderthalschädels," Verhandl. der anatomischen Gesellschaft in Bonn, 1901.

the Neanderthal skull possesses a number of important peculiarities which differentiate it from the skulls of existing man and show an approximation toward those of the anthropoid apes. He maintains that in recognizing with King[a] and Cope[b] the Neanderthal skull as belonging to a distinct species, *Homo Neanderthalensis*, he is only following the usual practice of zoologists and paleontologists, by whom specific characters are frequently founded upon much less marked differences. He maintains that as the Neanderthal skull stands in many of its characters nearer to the higher anthropoids than to recent man, if the Neanderthal type is to be included under the term *Homo sapiens*, then this species ought to be still more extended, so as to embrace the anthropoids.

It is interesting to turn from a perusal of these opinions recently advanced by Schwalbe to consider the grounds on which Huxley and Turner, about forty years ago, opposed the view, which was then being advocated, that the characters of the Neanderthal skull were so distinct from those of any of the existing races as to justify the recognition of a new species of the genus Homo. Huxley, while admitting that it was "the most pithecoid of human skulls," yet holds that it "is by no means so isolated as it appears to be at first, but forms in reality the extreme term of a series leading gradually from it to the highest and best developed of human crania." He states that "it is closely approached by certain Australian skulls, and even more nearly by the skulls of certain ancient people who inhabited Denmark during the stone period." Turner's[c] observations led him to adopt a similar view to that advanced by Huxley. He compared the Neanderthal calvaria with savage and British crania in the Anatomical Museum of the University of Edinburgh, and found among them specimens closely corresponding to the Neanderthal type.

While yielding to no one in my admiration for the thoroughness and ability with which Schwalbe has conducted his elaborate and extensive investigations on this question, I must confess that in my opinion he has not sufficiently recognized the significance of the large cranial capacity of the Neanderthal skull in determining the zoological position of its owner, or made sufficient allowance for the great variations in form which skulls undoubtedly human may present.

The length and breadth of the Neanderthal calvaria are distinctly greater than in many living races and compensate for its defect in height, so that it was capable of lodging a brain fully equal in volume to that of many existing savage races and at least double that of any anthropoid ape.

A number of the characters upon which Schwalbe relies in differentiating the Neanderthal skullcap are due to an appreciable extent

[a]The Reputed Fossil Man of the Neanderthal, Journal of Science, 1864.
[b]The Genealogy of Man, the American Naturalist, Vol. XXVII, 1893.
[c]The Fossil Skull Controversy, Journal of Science, 1864.

to the great development of the glabella and supraorbital arches. Now these processes are well known to present very striking variations in existing human races. They are usually supposed to be developed as buttresses for the purpose of affording support to the large upper jaw and enable it to resist the pressure of the lower jaw due to the contraction of the powerful muscles of mastication. These processes, however, are usually feebly marked in the microcephalic, prognathous, and macrodont negro skull, and may be well developed in the macrocephalic and orthognathous skulls of some of the higher races. Indeed, their variations are too great and their significance too obscure for them to form a basis for the creation of a new species of man. Both Huxley and Turner have shown that the low vault of the Neanderthal calvaria can be closely paralleled by specimens of existing races.

If the characters of the Neanderthal calvaria are so distinctive as to justify the recognition of a new species, a new genus ought to be made for the Trinil skullcap. In nearly every respect it is distinctly lower in type than the Neanderthal, and yet many of the anatomists who have expressed their opinion on the subject maintain that the Trinil specimen is distinctly human.

Important and interesting as are the facts which may be ascertained from a study of a series of skulls regarding the size and form of the brain, it is evident that there are distinct limits to the knowledge to be obtained from this source. Much additional information as to racial characters would undoubtedly be gained had we collections of brains at all corresponding in number and variety with the skulls in our museums. We know that as a rule the brains of the less civilized races are smaller and the convolutions and fissures simpler than those of the more cultured nations; beyond this but little has been definitely determined.

As the results of investigations in human and comparative anatomy, physiology, and pathology, we know that definite areas of the cerebral cortex are connected with the action of definite groups of muscles, and that the nervous impulses starting from the organs of smell, sight, hearing, and common sensibility reach defined cortical fields. All these, however, do not cover more than a third of the convoluted surface of the brain, and the remaining two-thirds are still to a large extent a terra incognita so far as their precise function is concerned. Is there a definite localization of special mental qualities or moral tendencies, and if so, where are they situated? These are problems of extreme difficulty, but their interest and importance are difficult to exaggerate. In the solution of this problem anthropologists are bound to take an active and important part. When they have collected information as to the relative development of the various parts of the higher brain in all classes of mankind with the same thoroughness with which they have investigated the racial peculiarities of the skull the question will be within a measurable distance of solution.

THE ANTIQUITY OF THE LION IN GREECE.

By A. B. MEYER.[a]

The descriptive images of the lion by the earliest Greek author, Homer,[b] are so realistic and true to nature (compare especially in the Iliad, XI, 544 sqq.), that they must be ascribed to direct observation,[c] yet this does not prove the existence of that animal in Greece in historic time. Aside from other possibilities, it is uncertain whether the passages in question originated as late as the entire Homeric epic on the soil of Asia Minor (Æolia, Ionia), or whether they belong to earlier continental (Thessalian) collections of hymns. Herodotus, from about 484 to about 430 B. C., records, in volume VII, pages 124–126, of his history, that there are many lions between the Achelous River in Acarnania and the Nestus, which flows through Abdera, and this he mentions in connection with the description of Xerxes's expedition through Macedonia in 480 B. C., when lions killed some draft camels. This passage is often cited. Aristotle (384–322 B. C.), in Hist. anim., VIII, 28, gives the same range, but seems to have taken it only from Herodotus.[d]

On this G. C. Lewis[e] remarks:

> The scientific character of Aristotle's researches in natural history gives great weight to his testimony. As he was a native of Stagira and had resided in Macedonia, he may be supposed to have had opportunities for verifying it; and we can not assume that he blindly followed the account of Herodotus, although at an interval of about a century he defines the range of the lion by the same two rivers.

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[a] Translation of A. B. Meyer's "Bis wie weit in der historischen Zeit zurück ist der Löwe in Griechenland nachweisbar?" Reprint from Der Zoologische Garten, vol. XLIV, 1903, pp. 65–73.

[b] The most important passages among ancient authors who refer to the lion have been brought together in an interesting manner by H. O. Lenz, in "Zoologie der Alten Griechen und Römer," pp. 126–140, Gotha, 1856. Compare also O. Keller, Tiere des klassischen Altertums, Innsbruck, 1887, and L. Meyer, Handbuch der griechischen Etymologie, vol. IV., p. 498 sq., Leipzig, 1902.

[c] Thus already Pictet, Les origines indo-européennes, vol. I, p. 422, Paris, 1859, and O. Schade, Altdeutsches Wörterbuch, 2d ed., vol. II, p. 548a, Halle, 1872–1882.

[d] According to Pausanias (second century A. D.), VI, 5, 3, lions sometimes came down as far as Mount Olympus. The famous athlete (pancratiast) Polydamos, without shield or weapon, is said to have there slain a large and powerful lion. Comp. Lenz, Zoologie der Griechen und Römer, p. 34, note 78, 1856.

[e] The Lion in Greece; Notes and Queries, second series, vol. VIII, p. 82, 1859.

Further, after calling attention to the fact that Aristotle corrected a nonsensical statement of Herodotus on the act of parturition of the lion, he adds:

* * * It seems very unlikely that Aristotle should have been able to correct the historian's account of the parturition of the lioness but not have thought it worth his while to verify the more obvious and patent fact of the occurrence of the lion in northern Greece.[a]

And on page 59 he says:

It is very improbable that * * * he should in two places (i. e., also VI, 31) have repeated so important a statement as that of the presence of the lion in the whole of northern Greece, from Abdera in Thrace to the confines of Æolia, without verification and upon the mere credit of Herodotus, whom he elsewhere designates as a fabulist and whose errors in natural history he points out and rectifies in several places.

All this, though not cogent, is so obvious that it is easily understood when the philologist and the historian do not question Herodotus's "account, so definitely presented and twice repeated by Aristotle, a native of that region."[b] Nay, J. Beloch[c] even adds: "That it [the lion] once spread over the whole peninsula (i. e., also over middle Greece and the Peloponnesus) is shown by the myths of the Nemean and Cithæronian lions."[d] On the part of philology there is thus apparently no ground to doubt the ancient tradition that even in historic time, about 500 B. C., there were lions in a part of Europe situated near Asia.

Turning from the ancient tradition to the domain of linguistic facts, we find among the Greeks a high antiquity of the lion's name,[e] unpar-

[a] Loc. cit., vol. IX, p. 56, 1860.

[b] O. Schrader, Reallexikon der indo-germanischen Altertumskunde, vol. I, p. 508 1901.

[c] Griechische Geschichte, vol. I, p. 37, note 1, 1893.

[d] The same was already maintained by Lewis, loc. cit., 1860, and Dawkins and Sanford have adopted it, as we shall see below, in 1869.

[e] Compare, in the first place, W. Schulze, Quæstiones epicæ, p. 70 et seq., Gueterslohae, 1892; so already Th. Benfey, Griechisches Wurzellexikon, II, 1, Berlin, 1842; F. A. Pott, Etymologische Forschungen auf dem Gebiete der Indo-Germanischen Sprachen, 2d ed., II, p. 1261, Lemgo, 1867; F. Kauffmann, in Paul und Braune's Beiträgen, vol. XII, p. 210, 1887 For the Celtic forms see W Stokes, Urkeltischer Sprachschatz, edited by A. Bezzenberger (=A. Fick, Vergleichendes Wörterbuch der Indogermanischen Sprachen, 4th ed., vol. II), p. 242, Göttingen, 1894; for the Slavo-Lettonian, J. Kartowicz (V. Jagic) in the Archiv für Slavische Philologie, vol. II, p. 364 1877, and A. Brückner, Die Slavischen Fremdwörter im Litauischen, pp. 103 and 105, Weimar, 1877; for the old high German, besides O. Schade, Altdeutsches Wörterbuch, 2d ed., vol. II, p. 547 sq., Halle, 1872–1882; also O. Bremer in Paul und Braune's Beiträgen, vol. XIII. p. 384–387, 1888, against F Kauffmann, ibid., vol. XII, p. 207–210, 1887, and H. Palander, Die althochdeutschen Tiernamen, vol. I, p. 46 sq., Darmstadt, 1899. Schulze (loc. cit.) considers the Greek name as the final source of all the other European designations, as a genuine Greek word, while L. Meyer (Handbuch der griechischen Etymologie, vol. IV, p. 499,

alleled in European Indo-Germanic languages, and this antiquity of the name makes it probable that it originally denoted an indigenous animal which could not have been other than the lion. But the existence of that animal in historic time is not thus proved, and the fact that philological studies leave us uncertain as to whether the name originally designated an indigenous animal leads us now to turn to zoology[a] for a possible solution of the problem.

Likewise, if we search among the place names for traces of the existence of the lion we gain nothing. True, the word λέων (leon) occurs as the name of a cape near Eretria and Lebena[b] in Crete, but these names certainly do not refer to the animal as native to the region, but merely indicate that the rock suggests a lion in shape.[c] What, then, is the attitude of zoologists and paleontologists toward this question?

C. I. Sundevall[d] expresses himself as follows: "From all this it becomes very probable that in 330 B. C. lions were still encountered in Macedonia, though very rare." It is as little doubted by A. Newton,[e] Dupont, Nehring, von Zittel (see below), and others. Dawkins[f] also refers, in agreement with Lewis,[g] to Xenophon[h] (from about 428 until after 355 B. C.) in regard to the occurrence of the lion in historic time in South Thracia, and adds: "It may have extended far over the Balkan Range into the valley of the Danube within the historic period of Greece."[i] Flower and Lydekker[j] follow Dawkins and Sanford without reserve.

1902) thinks it possibly a word borrowed from a non-Greek linguistic sphere. The primitive relationship between the European Indo-Germanic lion names is of late upheld particularly by O. Schrader (Sprachvergleichung und Urgeschichte, p. 362 sq., Jena, 1890, comp. Reallexikon der indogermanischen Altertumskunde, vol. I, p. 508 sq., Strassburg, 1901). I am indebted for the linguistic references to Dr. Oswald Richter, assistant in the Royal Ethnographical Museum at Dresden.

[a] As did already Förstemann, Zeitschrift für vergleichende Sprachforschung, 1852, vol. I, p. 495.

[b] Lebena itself, which was a Phœnician colony, is named after the cape. Compare Hebrew labi, "lion;" comp. J. J. Egli, Nom. geogr., 2d ed., p. 531, Leipzig, 1898, and H. Lewy, Die semitischen Fremdwörter im Griechischen, p. 7, Berlin, 1895.

[c] Philostratus expressly mentions λέων as well as δράκων among the plays of nature: "Nature causes mountains and mountain peaks to resemble animals as . . . the Cretan lion . . ." Comp. A. Fick in Bezzenberger's Beiträgen, vol. XXI, p. 265, 1896.

[d] Die Tierarten des Aristoteles, p. 47 sq., Stockholm, 1863.

[e] On the Zoology of Ancient Europe, p. 7, London, 1862.

[f] British Pleistocene Mammalia, pt. A, p. xxxiv, 1878.

[g] Loc. cit., vol. VIII, p. 82, 1859.

[h] Cynegaticus XI, 1.

[i] See also Dawkins and Sanford, British Pleistocene Mammalia, pt. iii, p. 166, 1869.

[j] Introduction to the Study of Mammals, p. 504, 1891.

If bones of the *recent* lion have not yet been found in Greece, it should be remembered that the limited researches made in that country render negative evidence of little account. On the other hand, fossil lion bones are found. Thus only recently, as Dr. T. Krüper at Athens informed me, Doctor Skuphos found such a skull. The fossil cave lion was spread all over Europe during the Diluvial period. "In Diluvial bone caves of Europe," says von Zittel,[a] "the cave lion, which does not differ from the lion now found in Africa and western Asia, occurs in solitary examples. In historic time it still inhabited southern Europe." Nehring has recently proved the existence of the Diluvial lion (*Felis spelæa* Goldf.) in the province of Brandenburg,[b] and previously also in Thuringia, Westphalia, Brunswick, Hanover, and the province of Saxony.[c] He remarks on that occasion: "As regards the question of the contemporaneousness of man with *Felis spelæa*, I can not help affirming it on the basis of my excavations in the gypsum quarry of Thiede (Brunswick)." We may expect an elaborate treatise by Professor Nehring on the Diluvial lion. He thinks, as he informed me, that about 20,000 years ago, during the steppe period, the cave lion roamed in Germany as far north as Brunswick. Dupont considers such fixing of dates impossible, and thinks that for the present we must be content with establishing the succession of forms (loc. cit.). He has variously proven the existence of *Felis spelæa* in Belgium.[d] Its occurrence in England has been fully discussed by Dawkins and Sanford,[e] who say that it completely disappeared at the end of the Post-Glacial or Quaternary period, and that no finds of prehistoric time have been made. The same investigators discuss[f] its occurrence also in France, Belgium, Germany, the Carpates, Italy, and Sicily. In the latter territory it is supposed (according to Falconer) to have existed contemporaneously with man. Thus, according to paleontological indications, the lion was once spread over almost entire Europe.

This fossil lion of Europe is, in the opinion of most investigators, identical with the lion of the present. Such identity was already asserted by D'Orbigny[g] in 1858–1861, and, later, Dawkins and Sanford, in their already quoted work,[h] in which they treated of the *Felis spelæa* with the utmost completeness and care, arrived at the conclusion "that there is not one character by which the animal can be distinguished from the living lion. It must therefore be admitted that

[a] Handbuch der Paläontologie, vol. IV, p. 676, 1892.

[b] Sitzungsberichte der Gessellschaft Naturforschender Freunde, Berlin, 1899, p. 71 sqq.

[c] Zeitschrift für Ethnologie, Verhandlungen, vol. XXV, p. 407, 1893.

[d] L'homme pendant les âges de la pierre, 2d ed., 1873, pp. 80, 89, 114, 118, etc.

[e] Loc. cit., pp. 151–160.

[f] Loc. cit., p. 160–161.

[g] Diction d'hist. nat. (1858–1861), vol. III, p. 429.

[h] The British Pleistocene Mammalia, pt. iii, p. 150, 1869.

Felis spelæa is specifically identical with the lion now living on the face of the earth." For practical reasons they recommend the use of the designation *Felis leo* var. *spelæa* to denote that variety which during the Post-Glacial period inhabited the caves of north and west Europe. In 1890 Nehring[a] declares, following the opinion of most modern investigators, that the cave lion, *Felis spelæa*, is "nothing else than a northern variety of the lion [evidently provided with a warm, shaggy skin] analogous to the northern variety of the tiger which occurs at present in south Siberia." Dupont[b] likewise observes: "The lion, the reindeer, and the stag of the Quaternary epoch, in the remains which have been preserved to us, as much resemble those which live at present as the ibis which was embalmed thousands of years ago resembles the ibis which embellishes the shores of the Nile. The American *Felis atrox* Leidy is also, according to Dawkins and Sanford, identical with *F. leo* var. *spelæa*, so that its range extended over Europe, through Russia and north Asia, and, by way of Bering Strait, into America as far south as Mexico (loc cit., p. 163).

All the deposits in which the bones of the cave lion have been found in the countries mentioned above are either Post-Glacial or Quaternary. But Dawkins and Sanford think it would be rash to, a priori, exclude the occurrence in the Pliocene time. They also point out that Aristotle calls the lion "rare," while Herodotus, one hundred and fifty years before, could still say there were "many," and they think that it decreased during that interval. They then further observe, following Lewis,[c] that Dio Chrysostomus, 80 or 100 A. D., speaks of the complete extinction of the lion, so that within four hundred years after Aristotle it disappeared from Europe.[d] Lastly, they lay stress upon the lion in the folklore of the Balkan peoples because this permits the conclusion of the simultaneous occurrence of the lion with man. This, too, is based chiefly on the data brought together by G. C. Lewis in his two extremely readable essays.[e]

Whatever weight may be given to the accounts or legends of the ancients or to the views of modern naturalists on the simultaneousness of man with the cave lion, there is at all events a connection between the former and present range of the lion, and since lions still roam not far from Greece its gradual retreat before man and civilization to the present limit of its range is not only not unlikely, but, on the contrary, most probable.

[a] Tundren und Steppen, 1890, p. 193.

[b] La chronologie géologique, Bull. Acad. R. Belgique, 3d series, vol. VIII, No. 12, 1884, p. 18 of the separate copy.

[c] Loc. cit., vol. VIII, p. 83, 1859.

[d] See also Dawkins, Die Höhlen und die Ureinwohner Europas, German translation by Spengel, 1876, p. 62.

[e] Notes and Queries, 2d series, vol. VIII, pp. 81–84, 1859, and vol. IX, pp. 57–59, 1860.

According to the Old Testament, the lion was common in the Lebanon region and even on the Jordan. It occurred in Palestine until the twelfth century (the time of the Crusaders).[a] In Syria its existence can be traced from the earliest historical times to the present day. According to Perrot and Chipiez,[b] Amenophis III (1400 B. C.) is proved to have chased the lion in northern Syria on a large scale. Only twenty years ago, according to Tristram (loc. cit.), the body of a lion was brought to Damascus. In Egypt proper, lions but rarely occurred,[c] while in northern Syria they must have been quite numerous. Ancient writers also—Xenophon, Aristotle, Strabo, Pliny, and others—speak of lion hunts in Syria and in Arabia. The lions in the latter country are said to have been more powerful and numerous than in Lybia. Tristram states that in Mesopotamia the lion is at present common. Layard, in the middle of the last century, heard its roaring not far from Bagdad. In the north it occurs on the Tigris as far as Kalaat Schergat, on the Euphrates as far as Bir,[d] and, lastly, in Persia,[e] where the lion is especially found "in the forest slopes of the Zagros," the chief mountain region of Persia. Abbott[f] mentions the lion among the animals of Khorasmia.[g] On its occurrence in northwest India, see Blandford (loc. cit.) and Dawkins.[h]

Considering all this, I hold it not well to be doubted, from reasons of natural science, that in Herodotus's time lions still lived in the regions named by him, and I hold it not impossible that the ancient lion representations in Greece, such as a lion chase upon a Mycenaean

[a] H. B. Tristram, The Survey of Western Palestine, 1884, p. 17. Comp. also his Natural History of the Bible, 7th ed., 1883, p. 116 sq.

[b] Geschichte der Kunst im Altertum: Aegypten, German translation by R. Pietschmann, p. 862, 1884.

[c] "The artists of the new empire were encouraged to a frequent representation of the lion above all through the renewed acquaintance with the animal itself, and one might think that this Asiatic lion possessed their imagination when they depict lions either with a very light mane or with none at all, if both varieties did not appear at Beni Hassan. At all events the lion with heavy mane is the more original type in Egyptian art . . . Only very rarely do the forms of the lion in Egyptian representations indicate the Assyrian type. The heraldic use of animals upon shields and pectorals is also of Asiatic origin, appearing in the second Thebean empire in pictures which exhibit gryphons, jackals, and lions." (Perrot and Chipiez, loc. cit.) Thus there occur upon Egyptian monuments both the Egyptian and the Asiatic types of lions (both wild and tamed), with a noticeable difference, which is worth consideration also in other parts of ancient archæology, as, for instance, in the study of the Greeks.

[d] Nineveh, vol. II, p. 48, 1849.

[e] Eastern Persia, vol. II, Zoology and Geology, by W. T. Blandford, 1876, p. 29, and W. Geiger, Grundriss der Iranischen Philologie, vol. II, pt. 3, p. 382, 1897.

[f] Narrative of a journey from Heraut to Khiwa, London, 1843, vol. II, p. 25, supplement.

[g] Comp. Pictet, Les Origines indo-europ., 2d ed., vol. I, p. 529, Paris, 1877.

[h] Die Höhlen, etc., 1876, p. 312.

dagger, were made from nature, viz, at a time when the animal still occurred there in a wild state. Lewis is of a different opinion, and says:[a] "The lions on the gate of Mycenæ are of great antiquity, but the occurrence of this animal in works of early art can not be considered as evidence of his presence in the country. Sculptured lions occur more than once in connection with Etruscan tombs, and there is no reason to believe that the lions ever existed in Italy * * *." But can this last objection be considered valid?[b] Besides, not all non-naturalists are of this opinion, as, for instance, Perrot and Chipiez:[c] "Unless we assume—and we have no ground whatever for so doing—that it was an object imported from without,[d] we must admit, notwithstanding all that has been said to the contrary, that the lion in those remote times still haunted the mountains of the Peloponnesus and central Greece, and that the engravers and sculptors, when they portrayed that animal, were able to do so from nature." Thus in the discussion of the earliest historic time more or less subjective opinions come into play, and natural science likewise can consider the question as solved only when the discovery of recent lion bones under incontestable circumstances gives positive proof. Of this, however, there seems little hope. At all events it might be suggested that in future excavations all animal bones be conscientiously collected and submitted to experts for examination.

[a] Loc. cit., vol. VIII, p. 81.

[b] Prof. P. Herrmann, of the Royal Sculpture Collection at Dresden, writes me: "The view of Lewis, which is based on the lion representations in Etruscan art, and quoted by you, is absolutely untenable. These Etruscan monuments are a thousand years younger than the Mycenæan and have, besides, their parallels in the contemporary art creations of the Greeks. No archæologist has maintained or will maintain of either of them that the lion images appearing on them were made from direct observation of nature. They are obviously borrowed from Asia. This shows itself clearly enough in the absence of the refined and free realism which characterizes the Mycenæan representations in such a high degree." Compare also the chapter "The lion and the lotus," in William H. Goodyear's The Grammar of the Lotus, London, 1891, pp. 205–211, with plates xxix and xxx (add. 1904).

[c] Hist. de l'art dans l'antiquité. La Grèce primitive, l'art mycénien, vol. 6, p. 823–826, figs. 402 and 403, 1894.

[d] I can not think that the idea of introducing captive lions which may have served as models for the artists should so lightly be rejected.

COLOSSAL MARBLE LION FROM A POLYANDREION OR MAUSOLEUM NEAR CNIDUS, SUPPOSED TO COMMEMORATE VICTORY BY ATHENIAN ADMIRAL CONON OVER LACEDÆMONIANS, 394 B. C. (ABOUT B. C. 300.)

THE EXCAVATIONS AT ABUSIR, EGYPT.

By Prof. Dr. A. Wiedemann.[a]

The traveler from Cairo ascending the Mokattam mountains sweeps his gaze westward and his vision is presently arrested by the great pyramids looming upward in rigid conventional forms on the tableland across the Nile as reminders of that old civilization of which they are the best known surviving memorials. In ancient days they must have been much more imposing than at present, for besides the few structures now visible, there stood on the opposite elevation more than 100 pyramids, as well as numerous temples and monumental tombs, while below them on the plain, where only isolated villages are now seen, there spread out one of the largest cities recorded by ancient history, Mennefer, "the beautiful place," Memphis of the Greeks. The "city of the dead," to which for nearly four thousand years the inhabitants of this great city were carried to their last rest, is marked by the pyramids. The width of this necropolis was not great, scarcely exceeding 2 kilometers, but its length has been estimated at 30 kilometers. The size of the "city of the living" was in proportion to the great necropolis, and under modern European conditions this would indicate an enormous city, surpassing in extent even the city of London (about 22 kilometers). We must not forget, however, that we are in the Orient where the crowding of buildings together is little in vogue, groups of houses being followed by broad gardens and fields, then other clusters of houses, or wide desert tracts, in checkered succession, so that a city is really nothing more than a collection of several separated localities. Oriental cities also frequently change their location; some portions are abandoned or become insignificant suburbs, while new quarters spring up by their sides. Such was the development of Cairo, where, by the side of the important city of Babylon-on-the-Nile of the old Egyptian and the Graeco-Roman periods, arose old Cairo, which soon surpassed it. Then, farther north, was developed the modern Cairo. Old Cairo has to a great extent gradually disappeared, while Babylon, as a small

[a] Translated from Die Ausgrabungen zu Abusir, von Prof. Dr. A. Wiedemann, in "Die Umschau," Wochenschrift ueber die Fortschritte auf dem Gesamtgebiet der Wissenschaft, Technik, Litteratur und Kunst. H. Bechhold, Frankfort-on-the-Main. Vol. VII, No. 26 (June 20, 1903), pp. 501–504, and No. 27 (June 27, 1903), pp. 532–536.

place, inclosed by the walls of a Roman fortress, survived it. Ancient Memphis likewise experienced a shifting of its principal center, the change of position being traced by the locations of the pyramids, for the Pharaohs liked to build their homes not far from their future burial places. Thus, at Thebes, the royal palace of Amenophis III was within the precinct of the necropolis, and the same custom was also observed at Memphis, as proved by the discovery of the remains of a royal palace beneath the foundations of a temple in the graveyard city. From the location of the pyramids and the succession of their builders it can be inferred that Memphis as a rule spread from north to south, though occasionally for a brief period the course was in the opposite direction. The site of the principal temple alone remained unchanged, though lesser sanctuaries to the same god might elsewhere be erected. Thus the temple of Ptah, the local divinity of Memphis who was widely believed to have created and to rule the world, lay between the Nile and the village of Sakkarah, while other sanctuaries, dedicated to the same god, arose in other parts of the city.

Near the present villages of Gizeh and Sakkarah lie the two necropolis districts of Memphis which have been most assiduously investigated by modern explorers and whose monuments produce a most imposing impression. A visit to these places is part of the stated programme of most travelers in Egypt. One frequently gets also a view of other monuments of the graveyard city that are situated more to the north and the south, between the above localities. Those to the north belong to the oldest remains of the kings resident in Memphis, while to the south are buried the rulers of the twelfth dynasty, who lived about a thousand years later. In the pyramids of Gizeh mummies of princes of the fourth dynasty were interred, while in those of Sakkarah they were chiefly of the sixth dynasty. The pyramids of Abusir, between Gizeh and Sakkarah, were constructed under the fifth dynasty and for a long time were believed to offer little reward to the visitor; for although a few isolated and beautiful graves were found in their neighborhood, they had become covered again by the sand, so that tourists found here little worth seeing. This circumstance was an advantage to the necropolis, for absence of strangers means also freedom from that petty plunder of antiquities dependent on daily sales which is, on the whole, more fatal to the monuments than the wholesale removal of plundered objects to be sold at a distance. As a result little excavating has been done here by the Arabs, and as the connections with Cairo are inconvenient, not much scientific exploration has been carried on. And yet such a work would have been profitable, as proved by the results of the excavations made by the Germans in the field of ruins during the last few years and which are briefly described in the following pages.

The attention of the first scholars who visited the graveyard of Abusir was attracted by the ruins on its northern end, near the opening of a shallow desert valley into the arable country. It gave the impression of a pyramid which, from a casual investigation, was ascribed to King Ra-en-user, of the fifth dynasty. Superficial excavations, especially those of Villiers Stuart, the English member of Parliament, brought to light temple remains buried underground. Thus matters stood until about 1898, when it was found that Arabian antiquity traders had here discovered a series of reliefs, which came to the Museum of Berlin. The subjects and the execution of these reliefs were interesting enough to make scientific excavations on that site desirable before all the antiquities there buried should become the prey of the natives and scattered to all quarters of the compass. The Berlin Museum undertook the work, for which Dr. Freiherr von Biss-

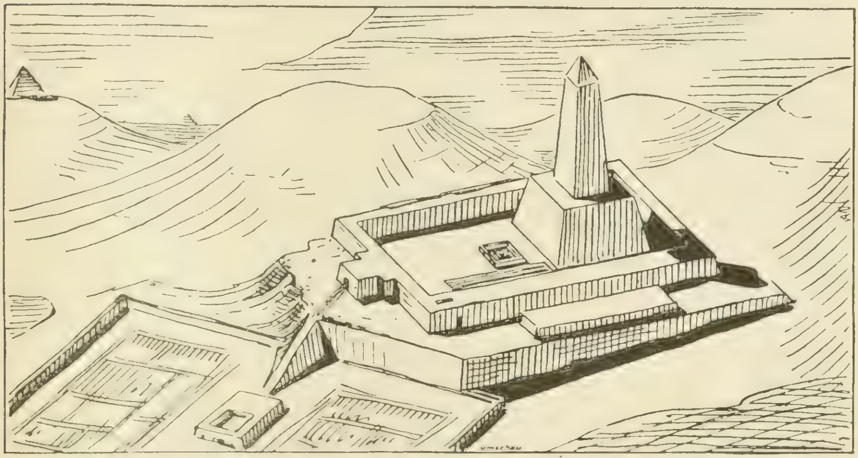


FIG. 1.—Reconstruction of sun sanctuary. (From Borchardt.)

ing furnished the necessary funds, and during the winters of 1898 to 1901 Drs. L. Borchardt and H. Schäfer brought the excavation work to a conclusion. There is as yet no final publication giving the completed results of their investigations, but from the preliminary reports it is possible to obtain an accurate survey of the essential achievements.

At the rear end of a rectangular walled inclosure, 75 meters wide and 100 meters long, there rose a pyramid with a blunted top, from the center of which projected an obelisk. (See fig. 1.) Within the court stood an altar constructed of gigantic alabaster blocks, and near it on one side were sunken channels, leading to alabaster basins, evidently to carry off the blood of the victims from the immediate vicinity of the altar. Behind the channels were numerous storerooms, while the east and south sides were occupied with passages whose

walls were once faced with slabs of limestone decorated with reliefs partly still preserved. Opposite the altar a gateway led into the large inclosure. An inclined pathway led to the gate, and thus connected the plain with the elevated sanctuary. The lower end of the pathway terminated in a monumental gateway which stood within another walled inclosure. The latter inclosed a quadrangular space about 300 meters square, which, with much exaggeration, was called a "city," though in reality the only residences here were those of the priests and officers stationed in the building. In addition to these Borchardt discovered outside the sanctuary, toward the south, brick masonry beside which lay remnants of decayed wood. As may be concluded from the form of the entire find, there once stood here a large wooden sacred bark resting upon brick foundations.

The reliefs just mentioned represent, first of all, some of the ceremonies accompanying the founding of an Egyptian sanctuary. The king and the goddess of the right measure determine the axis of the temple, make the opening for the foundation, offer the sacrifices of the corner stone, etc. Then the celebration of the Sed festival is depicted as it is also seen in the reliefs of numerous temples of the classical period of Egypt. The king sits upon a throne, then he descends the steps leading to the throne and is carried about on a chair. The people fall down before him; priests and officials follow him. Then he appears in various festal robes, his feet are washed, the royal children are brought in sedans, rows of sacred animals are led by, etc. Every representation of this festival formerly existed in duplicate, the Pharaoh performing these ceremonies on one side of the temple, being decorated with the insignia of a king of Upper Egypt, while on the other side he wears the vestments of a king of Lower Egypt. It is regretted that so far no explanation can be given of the object of the Sed festival, though it is so often mentioned in the inscriptions. In most cases the king appears to have celebrated the festival for the first time thirty years after his appointment as Pharaoh or crown prince, and then repeatedly at shorter intervals. It was at all events combined with religious solemnities, especially with the erection of obelisks, and it may be that the sanctuary described above was established on such an occasion.

Still more interesting than these reliefs are others representing the divinities of the Egyptian seasons in human form and behind them the images of the objects characteristic of each season. Plants and trees are depicted; birds flutter about or rest in their nests; fishes swim in the water; animals beget and bring forth young; men are engaged in fishing and fowling; they construct and use boats, till the soil, harvest figs and honey, brew beer, hunt in the desert, and raise cattle. Similar representations occur in the tombs of the so-called old Empire of Egypt (about 3000 B. C.) as pictures of the daily life in the

valley of the Nile, but those of our sanctuary are marked by greater unity of arrangement and completeness of grouping. Only a few of the ordinary customs of life appear in the decoration of temples of later times. It is evident that in ancient times daily life was held to be more worthy of preservation, while in later periods only the sublime objects, rather than the doings of every day, were deemed worthy of representation on reliefs in the house of God.

From what has been said it can readily be inferred that the structure described was not a pyramid tomb, but rather a sanctuary in whose inclosure sacrifices were offered upon an altar erected in the open court. Such altars in the open air belonged to the sun god. This deity was first of all embodied in his planet in the sky, whence he could look down upon the gifts and where he could receive the smoke of the burnt offerings. But a god afar off did not satisfy the ancient Egyptians in their worship. The god must be near the altar, where he could have the full benefit of the sacrifices, and usually this object was attained by having close at hand the sacred animal or the statue or emblem serving as the embodiment of the god, and which actually became to them the very god himself. This was the case in Abusir. The pyramid obelisk, before which the altar stands, is the sun god in the form in which he dwelt in the holy of holies of the temple of his most holy city of the valley of the Nile, named for him Heliopolis, "the city of the sun." Behind sealed doors, opening only to the elect, there stood a conical stone as divinity. Such a form of deity is often met with among the Semitic tribes, but whether their influences introduced it into Heliopolis or whether the natives of the valley of the Nile had similar conceptions of the sacredness of stones is still undetermined. All that is known is that from most ancient times the deity was here represented in this manner, but that in the course of centuries there arose an uncertainty as to the exact form of the conical stone, it being once conceived as a pyramid, then as an obelisk, and later, as at Abusir, as a combination of both. Near the god there stood in the temple two sacred barks used by the sun god for his journey across the heavenly ocean. One in the forenoon bore the newly resurrected sun, while the other in the afternoon carried the dying planet as it descended from the zenith. Similar to this was the grouping of the sacred objects at Abusir. The remnants of one of the barks was discovered during the recent excavations, but the other is still covered by the desert sands.

In the district of Memphis, however, the sun god was a stranger. Originally there reigned here Ptah, the god of Memphis, and Sokaris, the god of the adjoining district of Letopolis, the sparrow-hawk-headed prince of the realm of the dead, who gave his name to Sakkarah. When the fifth dynasty, whose members claimed descent from the sun god, ascended the throne, the kings endeavored to introduce

the worship of their heavenly ancestor also into the district of their capital. He could be sure here of a ready reception, for the Egyptian gods were not exclusive and were always ready to make room for other heavenly powers in the sanctuaries as long as their own cult was not prejudiced by it. The inscriptions teach us that gradually several pyramid obelisks were erected in the vicinity of Memphis.

According to the Egyptian view, at the moment when the image of a god was completed in the prescribed form there came into existence a new god, and in the study of these structures this belief is of fundamental importance. The new god was equipped with all the rights and duties of the original divinity who was imitated by the image. He lived as long as the image lasted, and after its destruction passed away as a dead god into the other world. On this account old images of gods were occasionally buried in order to give the corpse of the god a proper resting place. The logical contradiction appearing in the juxtaposition of numerous similar divinities, as shown by the multitude of divine images, disturbed the Egyptians no more than did the many other unlogical elements which the sun-god religion presents to modern critics. The object of worship in the edifice of Ra-en-user was accordingly the representation of the sun god newly created by the King; for him were intended the sacrifices which were offered upon the large altar. From the platform upon which the sanctuary stood the god could look down upon the worshipping multitude as it approached him. The discovery of this god image and its place of worship was the achievement of the excavations just described.

From what has been said it follows that the northernmost large mound of ruins at Abusir did not contain the tomb of King Ra-en-user. Succeeding investigations made it clear that this must be somewhat south of the sanctuary beneath a shapeless heap of débris, about thirty meters high, the remains of a pyramid adjoined on its eastern side by a large field of ruins. The excavations of the German Orient Society, under the direction of Dr. L. Borchardt, have since 1901 been devoted to this site. In the pyramid, which had already been opened, little of importance could be expected, but the adjoining field of ruins that covered the mortuary temple of Ra-en-user was more promising. Sanctuaries serving the same object had already been discovered near other pyramids. The temple recently examined made it possible to follow up, with their aid, the development of beliefs in the relation of the living to the dead in the early times of Egypt.

The tomb was at first nothing but a hole in the desert sand, into which the earthly remains of the dead were laid either in parts or the entire body, as skeleton or mummy, with or without a coffin. By their side were placed some pots and bowls with food and drink for the deceased, whose physical needs were the same in the other world as in this. Gradually it became the custom to furnish the graves

more elaborately, until the gifts were so numerous that the simple grave could no longer hold them. Other rooms were then added, and the grave became a storehouse in which the gifts were placed either whole or broken into fragments. In the former case it was assumed that the deceased would himself use them in the grave which formed his dwelling place; in the latter case it was believed that he sojourned in the other world in an abode which was the counterpart of his grave. The new body corresponded to the corpse, and in the same manner the fragments had their real counterparts. In place of real offerings plastic imitations were frequently substituted, especially in later times, or their images were merely painted on the walls of the tomb, and aided by magical formula the dead could give them real existence. Such pictorial offerings were less costly and were less exposed to decay than real objects, and could afford the necessary basis for the constant renovation of the food articles and other needful things.

These tomb structures at first lacked a place of worship. As no offerings were found in the earth above the grave to indicate that ceremonies were observed after the interment, it is inferred that in the most ancient time the obligations of the survivors ended with the burial, so that the deceased could afterwards claim no more gifts. This conception, however, gradually underwent a change, and it was considered requisite for the welfare of the departed that from time to time new sacrifices should be consecrated to him and gifts be presented at his resting place. Rooms separate from the grave chamber became desirable, and such rooms indeed appear in Egyptian tombs from about the time of the pyramids until the passing away of the old religion. These are above the earth, separate from the inaccessible grave, and are open to visits from the living.

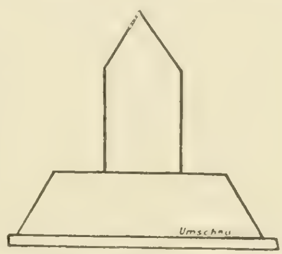


Fig. 2.—Sun obelisk, from a contemporary relief.

In the pyramids the grave proper was in the closed interior of the structure, where the offerings were placed next to the coffin, or, since the fifth dynasty, were painted on the walls. In front of the pyramid there was sometimes erected a mortuary temple. The oldest edifice of this kind known was at the pyramid of King Snefru, a ruler during whose reign the transition from the later stone age to that of the strictly historical dynasties in its various directions was accomplished. This building is unfortunately for the most part destroyed, there remaining only a covered winding path that led to a small room containing an altar and adjoining the pyramid. At the temple of the pyramid Chefren, which is in a better state of preservation, a straight passage leads between storerooms to the sacrificial hall, while in the

temple of Mycerinus storerooms lie to the right and left of the holy of holies. The importance given to storage places in these building plans shows the old significance of the tomb as a repository for the dead, the place of worship being only a secondary consideration.

In the later mortuary temples of the period following from about 2000 B. C. this relation is reversed. It is true they still have storerooms for the treasures of the sanctuaries, but they are of less importance in the general plan. The temple has here become essential. Such a change was made necessary by the development of the Egyptian religion, for no longer was it the real gift or action that was important, but the magical formula. If one wished to convey something to the deceased, he was more certain of success by pronouncing the prescribed magical words than by the offering of real objects.

This transition from the old temple with storerooms to the later cult temple, which heretofore had only been surmised, is now made clear by the excavations at Abusir. Here is found a complete temple with the usual arrangement of later times. In the rear rises the holy of holies not far from the pyramid. In front of it is a broad, covered room corresponding to the later covered court and leading to the open court, around which a covered passage runs. Its back wall is formed by the terminating masonry of the temple, while its front rests on tastefully shaped columns carved with papyrus designs. In the middle of the court a rain basin is sunk, from which an outflow leads outside the court.

This construction proves that the middle part of the court was from the first intended to be uncovered, and it also refutes the still frequently repeated assertion that no rain fell in ancient times in Egypt. At a more recent period the Egyptian temple terminated with such an open court, its entrance forming a monumental, fortress-like gate, the so-called "pylon," but at Abusir this was not yet the case. A simple door here leads into the court and a long passage leads up to it from the opposite direction. To the right and left of the passage are storerooms that have their continuation in still other passages surrounding the entire building and even extending to the north of the temple in front of the pyramid. At the end of the main passage is the entrance door, which was reached from the plain of Memphis by a slanting, inclined path. The storeroom plan is thus still retained, but it is only externally, not organically, attached to the cult rooms, which on their part have become an independent temple.

The temple just described is not located before the center of the pyramid, but before the southern part of the east side. In the course of the excavations at Abusir it turned out that the storerooms of the temple extended northward on the east side of the pyramid, and that between them and the center of the pyramid there was a large structure which on the front side of the pyramid was shut off by a large blind door. This building was not the holy of holies, or sanctum, of

the pyramid temple, as it was supposed; for the sanctum—the room in which the solemn sacrifices were performed—was in Egypt, as elsewhere, an organic part of the temple. It seems to me probable that the blind door was to serve as a passage for the deceased when he wished to leave the pyramid, his tomb. It had thus the same object as the blind doors frequently painted or sculptured upon the Egyptian coffins or tomb walls. The departed king could pass through this door to the building near the sanctum, and from there assist at the sacrifices, listen to the prayers, and inhale the odor of the offerings. It thus served the same purpose as the so-called "serdab" or narrow vaulted chamber found in the private tombs, the so-called "mastaba," alongside of the cult room, with which it occasionally communicated by a narrow opening. In this serdab there was usually placed a statue of the dead, in which he could embody himself and participate in the sacrifices offered in his honor.

This door also served the dead pharaoh as passage when he wished to revisit the earth and as specter to remind the living of the oblations to be offered to him, and to manifest upon earth the divine position to which he attained by dint of the magical formula. It may seem strange that this outlet for the deceased led not directly to the grave temple, but to a structure lying aside from it. The reason of this arrangement, also found in the mastaba, is probably to be sought in the belief of the Egyptians, of which numerous indications are found in the texts, that the souls of the dead, when not receiving a sufficient amount of offerings, and consequently in want of nourishment, would crowd at the gates of the locality searching the garbage heaps for food and attacking and robbing passers by. For this purpose they would also gather before the temples and the entrances to the tombs, whither offerings of food were brought and refuse dropped. It was therefore dangerous for the occupant of the tomb to pass such hungry predatory souls. The blind door located off the temple was to enable the dead to pass from the grave into the open unseen by the hostile souls, and thus escape the danger of being attacked by them. Thus also this find at the pyramid of Ra-en-user harmonizes in an excellent manner with what we otherwise know of the old Egyptian religious views.

The walls of the edifice are adorned with reliefs that in part correspond to the usual representations in the tombs of the valley of the Nile. We find here the killing of the sacrificial animals, the leading them up in procession, the long rows of women who, as representatives of the possessions of the departed, offer gifts. Alongside of them stand images which usually are seen only in temples—adoration of various gods by the king; the massacre of captured enemies whom the ruler kills with an uplifted club, etc. In these two kinds of pictures the twofold object of the edifice, that of tomb and temple, finds a distinct expression. In this connection it is interesting to observe

that the manner of presenting these groups, just as in the reliefs of the sanctuary of the sun god at Abusir, discussed above, corresponds almost exactly to the mode of presentation shown in the temples of the flourishing period of Egypt one or two milleniums later. The same characteristics are found in the architectural forms, the columns, cornices, and other features. It is therefore concluded that the view of the older investigators, that the art of the old empire of Egypt did not differ in principle from that of the later periods, was correct. The art of the later periods shows comparatively insignificant differences, due to the progressive development of the people. This conclusion, however, has of late been frequently disputed. Monuments whose inscriptions indicate very early time, but that exhibit peculiarities known only in later periods, have been declared to be in reality products of these later periods artificially given an archaic appearance; but the finds at Abusir show that these conclusions are erroneous and that such monuments are really as old as the names of the kings that they bear.

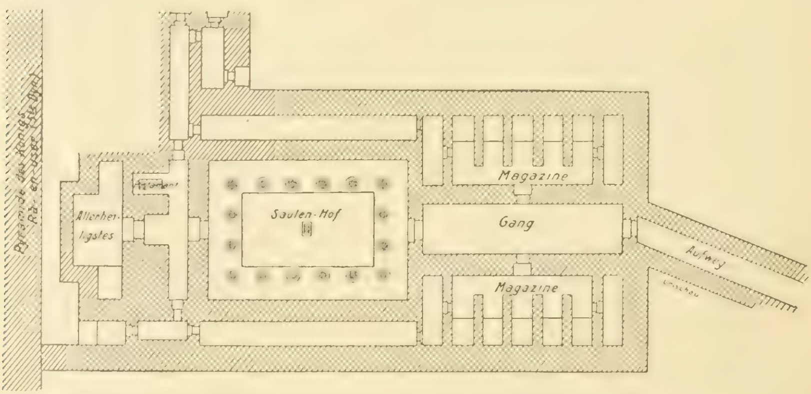


FIG. 3.—Plan of the Pyramid Temple of Ra-en-usur.

The mortuary temple of King Ra-en-user is as little finished as most old Egyptian edifices of this kind. The king died before the last hand was put on the work, and his successors had so much to do with their own buildings that they felt no inclination to spend time and strength on the foundations of their predecessors. But this pharaoh left endowments on the income of which priests were appointed to exercise his cult of the dead, and centuries later these functionaries are still mentioned, though the temple was in process of decay, for graves of that time have been found dug into ruin heaps above the temple floor. Shortly afterwards the cult, too, ceased, the walls of the temple were torn down, and the stones used for other buildings; high heaps of débris accumulated, common graves for the poor were made there, and a mound of ruins soon covered the entire site.

On the occasion of these excavations tombs of widely separated epochs of Egyptian history were opened in the neighborhood of the

OBELISK OF HELIOPOLIS AT MATARYÈH, EGYPT.

TIMOTHEUS PAPYRUS, COLUMN I.

From Der Timotheos-Papyrus, by Wilamowitz-Möllendorff.

temple described above. There were mastaba tombs of the old empire with the statues of their former occupants, and nonviolated tombs of the middle empire (2500 B. C.) with all the paraphernalia which those left behind had once placed for the departed in his grave. The tombs of the flourishing period of later Egypt were very poorly fitted out, and it is only with the Greek settlements in the country that costly interments again come to light.

THE TIMOTHEUS PAPYRUS OF THE PERSAI.

In one of the graves of this Greek period at Abusir was discovered, on February 1, 1902, a papyrus roll containing a large portion of the poem Persai of Timotheus. The papyrus was found in a wooden coffin still containing its corpse, together with a pair of sandals, a broken leather bag, a piece of rust-eaten iron, and a fragment of burned wood. All these objects are now at the Royal Museum of Berlin, and the papyrus has been published with a transcription, paraphrase, comments, and a facsimile reproduction in heliogravure, by Prof. Dr. Ulrich von Wilamowitz-Moellendorff.[a] The papyrus measures 18.5 centimeters in height and when unrolled has a length of 1.11 meters. It is inscribed with six columns of varied width and unequal number of lines in archaic Greek characters, resembling the style of monumental inscriptions, so that in the opinion of Professor Wilamowitz this papyrus represents the oldest book known, antedating the founding of the library of Alexandria and the establishing of the Alexandrian book trade. The four last columns are on the whole well preserved, while the first column, not protected by covering, is crumbled into minute fragments, and of the second column the lower half is for the most part destroyed. A narrow margin on the first column, showing traces of having been cut through, proves that only part of the scroll had been deposited in the grave. We have, therefore, in this papyrus only the latter portion of the work. The fact, however, that Timotheus names himself as its author and that it treats of the naval defeat of a Persian king suffices to establish its identity with the Persai of Timotheus, which celebrates the naval victory of the Greeks over Xerxes, the King of Persia, in 480 B. C. at Salamis, which was one of the decisive battles in the Græco-Persian wars. Timotheus is known to have been a celebrated poet and musician, born at Miletus, Asia Minor, and died at an advanced age about 357 B. C. He was especially distinguished as a composer of the so-called "nome," an ancient song or ode in the epic style, consisting of a narrative interwoven with speeches of

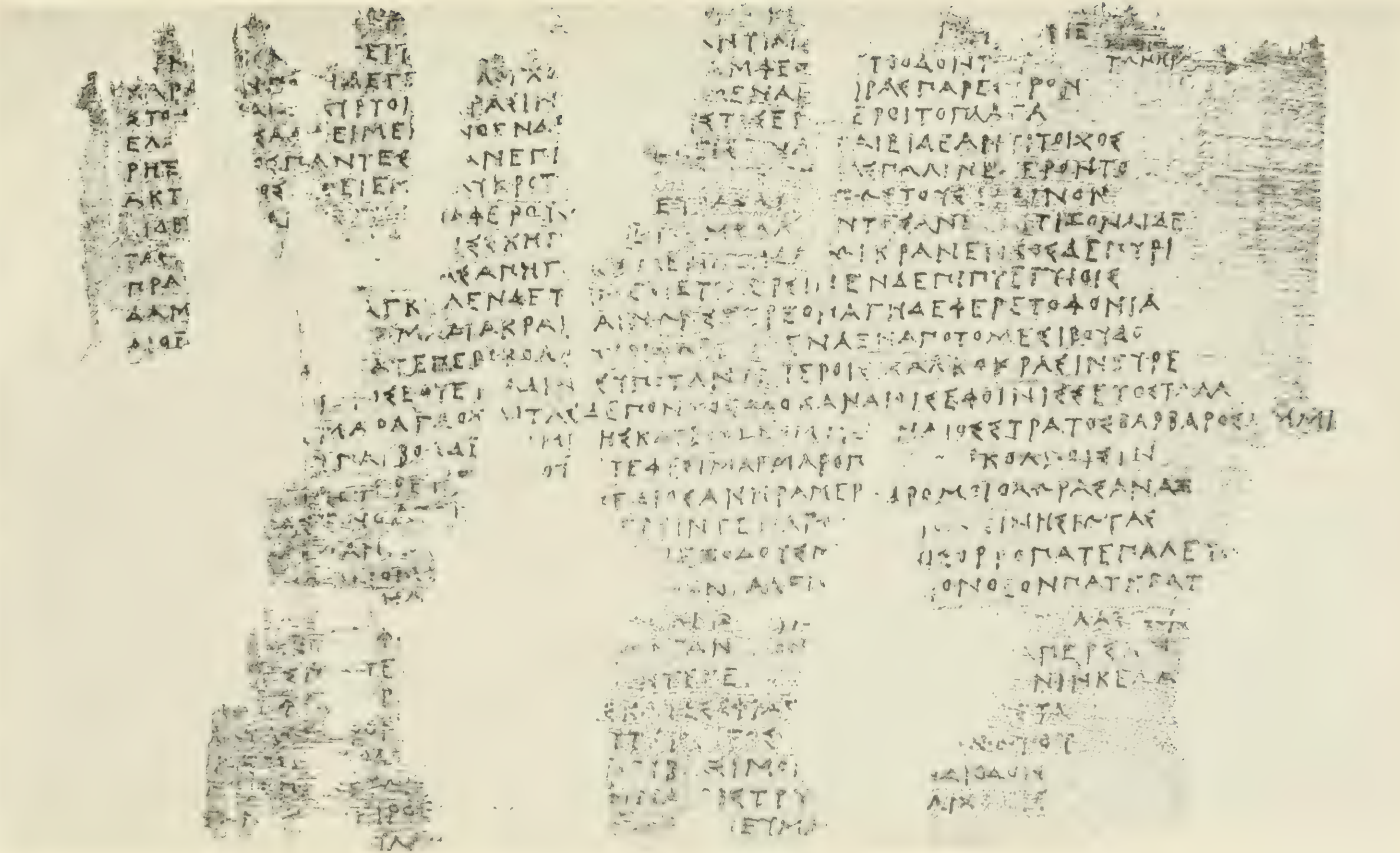
[a] Der Timotheus-Papyrus: Wissenschaftliche Veroeffentlichungen der Deutschen Orient-Gesellschaft, Leipzig, 1903, pp. 15, 4to., with 7 plates; and Timotheus, Die Perser, aus einem Papyrus von Abusir. Im Auftrage der Deutschen Orient-Gesellschaft herausgegeben, Leipzig, 1903, pp. 126, 8vo., with 1 plate.

introduced characters, and sung to the accompaniment of the lyre by the poet himself on festival occasions in honor of some god. He is also recorded to have increased the number of the strings of the lyre to eleven, by which innovation he incurred the displeasure of the Spartans, who considered it to be a corruption of music. But of the numerous compositions credited to him by later writers only a few fragments survive[a], and of the Persai only three verses were known. The Persai is also in the form of a nome and was first recited at the Panionion festival in honor of Poseidon, about 398 B. C. The part of the nome contained in this papyrus begins with the principal section of the poem, the omphalos, comprising the narrative. The ships are fitted out; the battle begins; the vessels dash against each other; lances fly about; firebrands whir in the air, setting the ships afire, from the glare of which the "smaraged" sea is reddened. The Persian fleet is put to flight; one rich follower of the Persian king battles with the waves, cursing the treacherous sea, and at last sinks while professing his hope for the victory of his king. Other Asiatics cling to rocks in the sea and bewail their imminent fate of death or captivity. At last panic seizes also the royal headquarters, and the king, under lamentations, orders a general retreat of his motley army. The victorious Greeks erect a trophy to Zeus and celebrate their victory with dance and song. In the epilogue the poet refers to himself, defending his innovation in music against the reproof of the Spartans, and invokes Apollo to "give the people peace and blessing resting on the observation of the law."

Of the details of the old Egyptian grave finds a better estimate may be formed when the results of the digging still in progress become available.

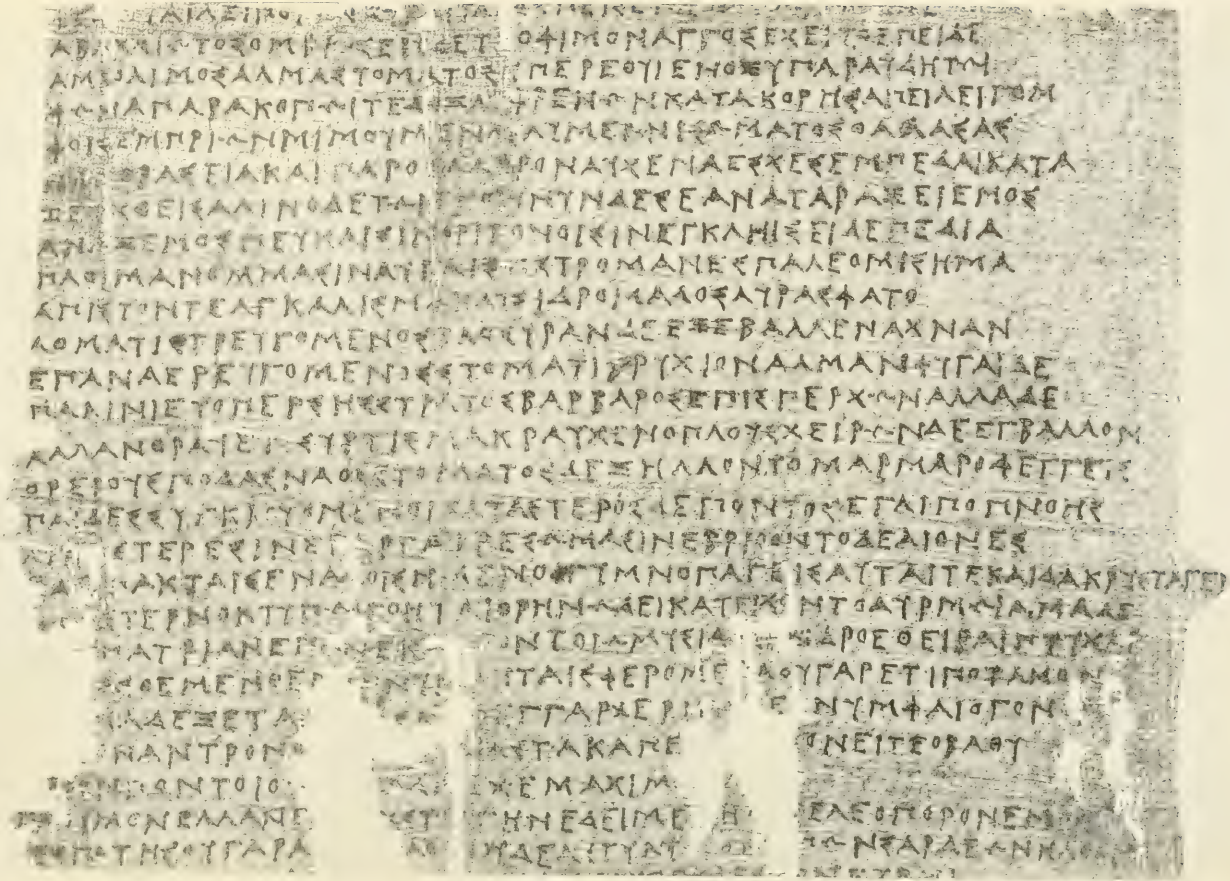
The excavations of the German Orient Society on the soil of the ancient Valley of the Nile have not received the same consideration from the great public as the diggings of the same society in Babylonia. To the latter attention was directed by the lectures of Friedrich Delitzsch, although their contents were but loosely connected with the excavations. The Egyptian work has not received the same treatment. Considering the real scientific results of the excavations in themselves, it can not be denied that the Egyptian explorations of the society, directed by Borchardt, have at least been crowned with as great a success as the Babylonian. It is to be hoped that the continued interest of the Government, as also the increasing number of members, will place the society in the condition to pursue its explorations with equal vigor in both of these countries whose civilization dominated early antiquity and likewise to extend its research to the countries lying between them, Palestine and Syria.

[a] Collected by T. Bergk in his Anthologia Lyrica, 3d edition, Leipzig, 1883, pp. 340–343.



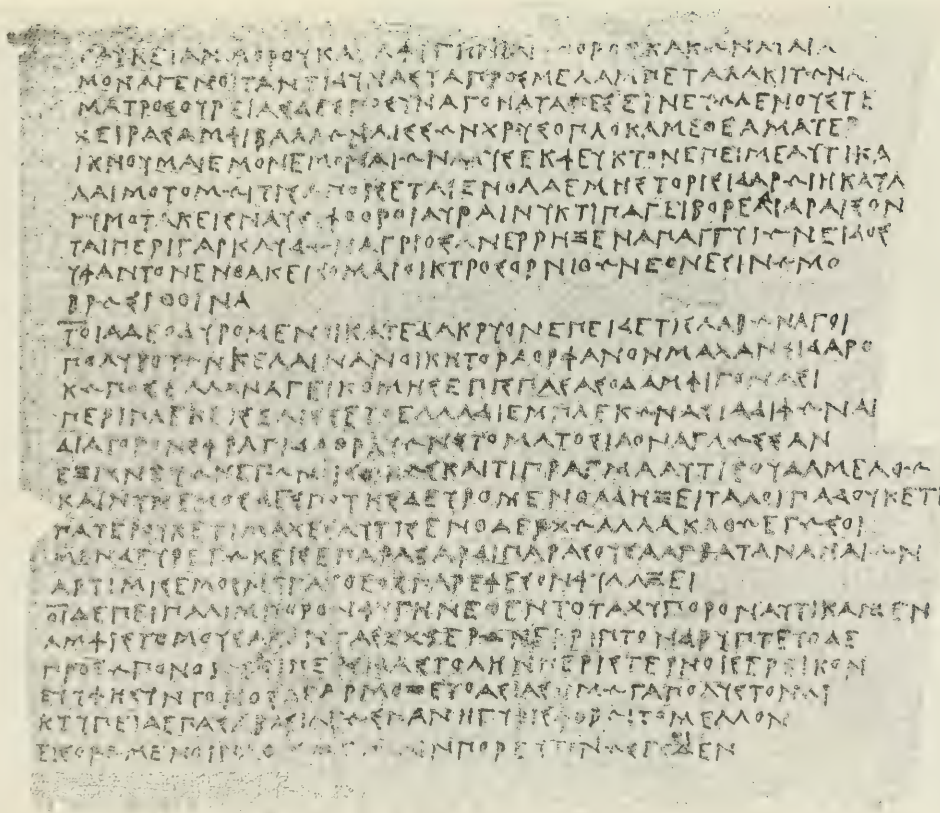
TIMOTHEUS PAPYRUS, COLUMN II.

From Der Timotheos-Papyrus, by Wilamowitz-Möllendorff.



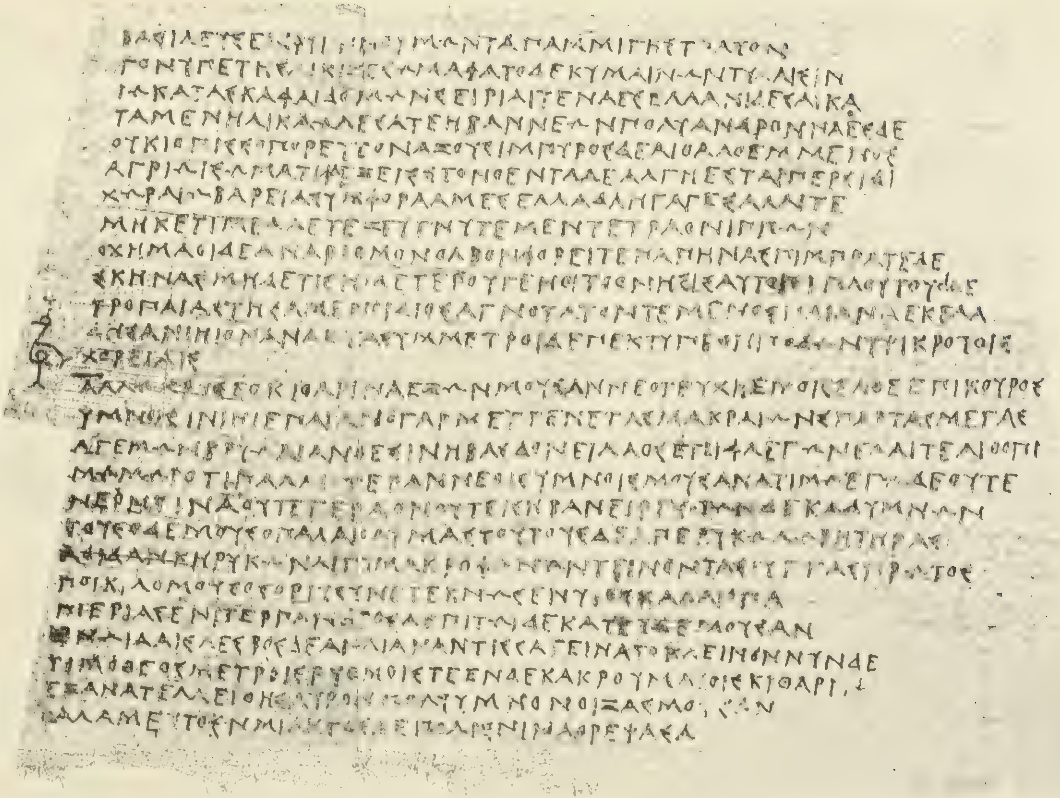
TIMOTHEUS PAPYRUS, COLUMN III.

From Der Timotheos-Papyrus, by Wilamowitz-Möllendorff.



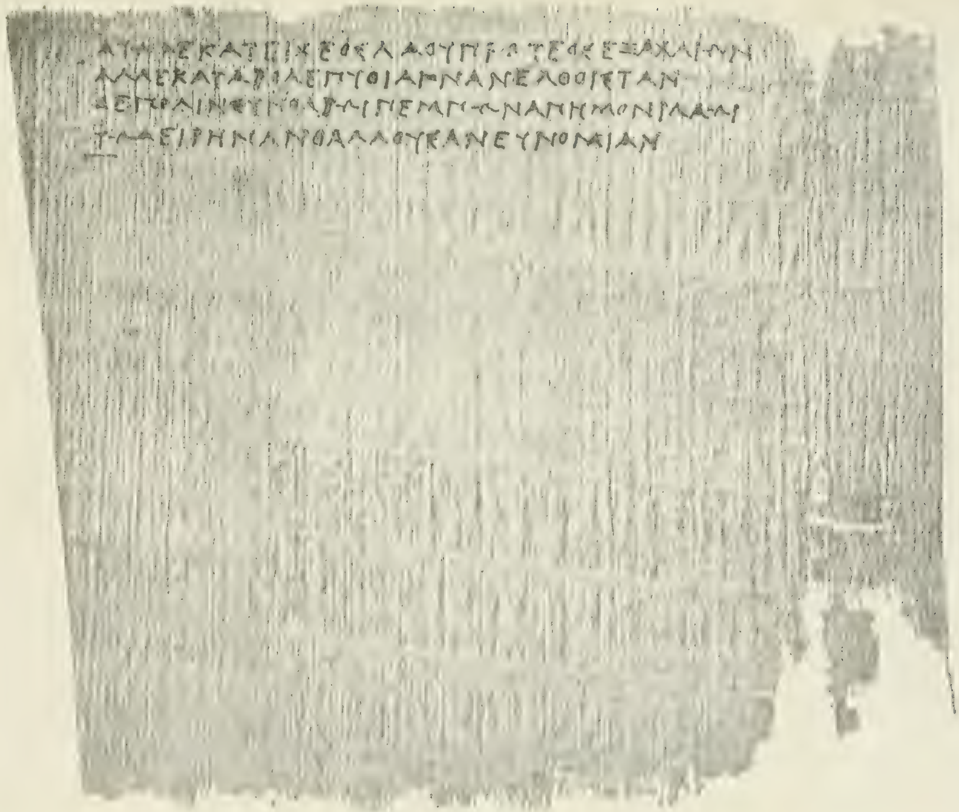
TIMOTHEUS PAPYRUS, COLUMN IV.

From Der Timotheos-Papyrus, by Wilamowitz-Möllendorff.



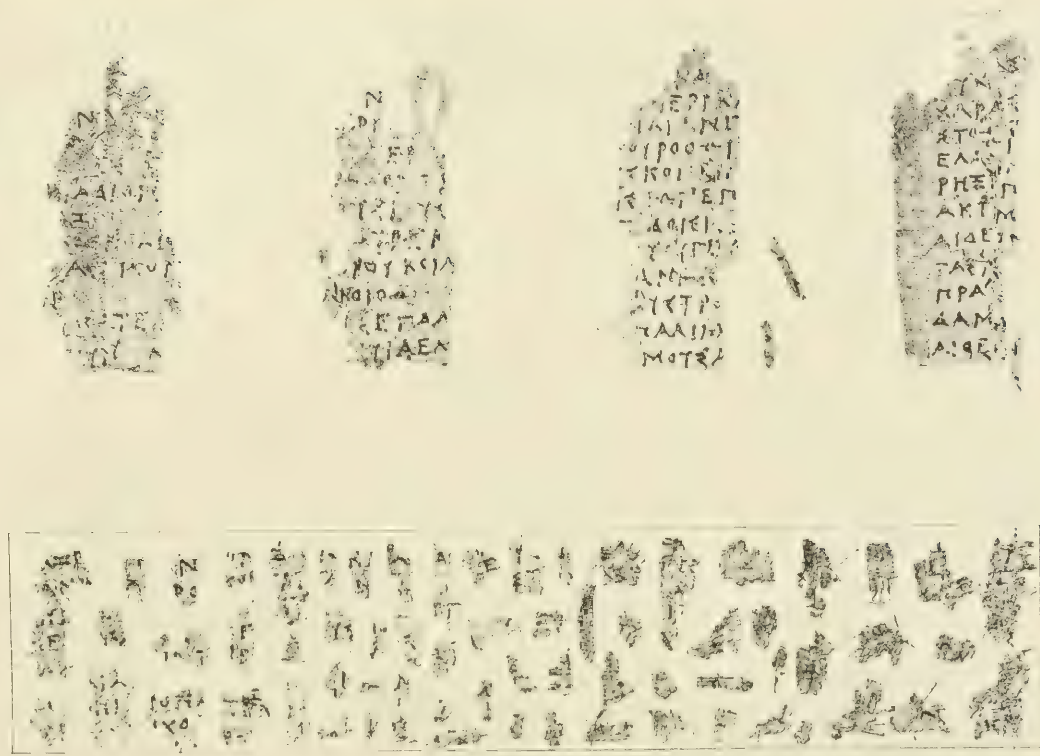
TIMOTHEUS PAPYRUS, COLUMN V.

From Der Timotheos Papyrus by Wilamowitz Mollendorff



TIMOTHEUS PAPYRUS, COLUMN VI.

From Der Timotheos-Papyrus, by Wilamowitz Moellendorff.



TIMOTHEUS PAPYRUS, FRAGMENTS.

From Der Timotheos-Papyrus, by Wilamowitz-Möllendorff

THE ANCIENT HITTITES.

By Dr. Leopold Messerschmidt.[a]

In addition to the two great spheres of ancient culture found in western Asia, the Egyptian and the Babylonian, we meet in the north, chiefly in Asia Minor, a third element which we are accustomed to call the Hittite civilization. We have as yet comparatively little knowledge of this people and their history, for only in one or two places have there been thorough excavations. The Hittite inscriptions themselves have not been deciphered, and the Egyptian and Assyrian inscriptions give only such meager items as records of warfare required. The Old Testament, to which until now our acquaintance with the name of the Hittites has been chiefly due, is too remote from the events in time and place and too indefinite in details to be of much service. Although our knowledge of the Hittites is thus, in many respects, so incomplete, yet we are able to construct a somewhat connected picture of the development of their civilization.

Egyptian and Assyrian inscriptions tell of warfare from about 1500 to about 700 B. C., with various peoples in North Syria, North Mesopotamia, Cilicia, Cappadocia, and Armenia. These peoples were neither Semites nor Indo-Europeans, yet they must have been interrelated as parts of a great group of peoples or common race. In favor of this view, the names of persons and gods come down to us which by their identical formation bear evidence of relationship and it is moreover improbable that entirely distinct races would at about the same period, and partly mingled, advance in the same direction and toward the same regions. On the other hand, it is self-evident, and proven also by certain facts, that these individual peoples, notwithstanding their general connection, were really distinct from one another in culture and in dialect, a phenomenon well known among the Semites as well as among the Indo-Europeans.

One of these peoples, known through Egyptian inscriptions as the Cheta, or Chatti according to Assyrian inscriptions, must be mentioned at once, since the name is significant, for we are accustomed to designate the entire group as "Hittites," their individual names being

[a]Translation of Die Hettiter, von Dr. Leopold Messerschmidt. Part 1 of vol. IV of Der alte Orient. Leipzig, J. C. Hinrichs, second enlarged edition, 35 pp., 8vo, 1903.

unknown. Consideration must therefore be given in each case as to whether the name Hittites denotes the individual Chatti people or the entire race.

In the regions where the Egyptians and Assyrians were at war with the Hittites there has been discovered during the last decade a complete series of remarkable monuments, with and without inscriptions, which doubtless bear witness to a pecular and independent civilization alongside of the Egyptian and Babylonian culture. The places of the finds, and particularly the agreement between subjects pictured and traditional evidence, lead to the assumption that we have here to do with monuments of the Hittite peoples. Similar monuments have been found scattered through the whole of Asia Minor, as far as Smyrna on the coast of the Ægean Sea, more numerous in the east, less frequent in the west. Keeping the above in mind, added to information derived from the Assyrian inscriptions, we must consider Asia Minor as the home of the "Hittites" and of their civilivation, from which country they advanced in successive movements southward and south- hence they immigrated into Asia Minor, whether from the west, which indeed is very probable, can not yet be positively determined.

The historical development of the Hittite race, its rise and disappearance, has been described in a former paper,[a] and will therefore here be but merely briefly repeated, with some additional information. The beginning of Hittite civilization on the soil of Asia Minor dates back to the third millenium before Christ, when Syria and Mesopotamia were under Babylonian rule. We assume an advance of Hittite peoples toward Syria and Mesopotamia about 2000 B. C., in the course of which they wrested these countries from Babylonian domination, for at the period when our documents begin to speak—that is, in the Tell el-Amarna letters,[b] in the fifteenth century B. C.—we find that peoples of the Hittite race had for a long time been in possession of these regions.

The first stratum of the Hittites which through the above-mentioned letters enters our horizon is the Mitani people,[c] but whether they were really the first of the Hittites to advance as far as Syria, or, what is more probable, whether they were preceded by others, none of our documents answers with certainty. But the kingdom of the Mitani, under their king, Tushratta, meets us at once as a great power equal to Babylonia and Egypt, comprising Melitene and the territories to the southeast of it, then northern Syria and northern Mesopotamia, with Nineveh, which was later the capital of Assyria. Still, the power of this kingdom is evidently strongly on the wane. It must formerly,

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[a] Der alte Orient, vol. I, part 1, 2d ed., pp. 18–28.

[b] Der alte Orient, vol. I, part 2, 2d ed., p. 3 ff.

[c] Der alte Orient, vol. I, part 2, 2d ed., p. 14 ff.

probably in the sixteenth century, have extended far southward into Syria to Mount Lebanon, as we have evidence that the language of the Mitani was spoken in Dunip (= Heliopolis = Baalbek). And the unnamed power against which Thothmes I, about 1500 B. C., and Thothmes III carried on war in Naharina was probably the Mitani kingdom.[a] But soon after the Amarna period, already in the fourteenth century, rising Assyria overthrew the Mitani kingdom and took possession of Mesopotamia.

While the Mitani must have advanced toward the south, in the seventeenth or sixteenth century B. C., we see the Chatti, or individual people of the Hittites, just at the Tell el-Amarna period, in the fifteenth century B. C., invading Syria from their native country, Cappadocia, and continually advancing southward. Through the weakness of Egypt, and for a time also the waning power of Assyria, the Mitani in the course of the fourteenth and thirteenth centuries subjected entire Syria to themselves as far as Mount Hermon. At the acme of their power, in the twelfth century, they meet the readvancing Egyptians under Ramses II in various battles, one of which, the attack of the Egyptians on the city of Kadesh on the Orontes, became well known, as the subject of a great Egyptian poem which extolls King Ramses in an extravagant manner. From these times dates also the oldest surviving example of a treaty between nations. This treaty was concluded between Ramses II and Chattusar, the king of the Chatti. The original was inscribed on a silver tablet in Babylonian script and language, as is now clearly established, and shows that Babylonian was even then, about 100 years after the Amarna period, still the international language of diplomacy.[b] But it is only the Egyptian translation which the Pharaoh caused to be engraved in the Temple of Karnak, that has come to us. On this occasion the royal scribe added an introduction, according to which the question was of a conclusion of peace which the Hittite king had entreated from Ramses. As a matter of fact it is Chattusar who draws up the treaty nor are there any fixed conditions of peace. The treaty rather contains general assurances to abstain from hostilities against one another, probably thus meeting a mutual need, and in addition there is the conclusion of a defensive alliance against internal and external enemies. The interesting contents of the document justify its presentation here in nearly complete form after the latest translation.[c]

[a] Der alte Orient, vol. I, part 2, 2d ed., p. 31.

[b] Der alte Orient, vol. I, part 2, 2d ed., p. 4.

[c] By W. Max Mueller: Der Buendnisvertrag Ramses II und des Chettiterkoenigs. Mitteilungen der Vorderasiatischen gesellschaft. 1902. 5. For the changes made in the interest of clearness I was kindly supported by the Egyptologist, Dr. Moeller. The text of the treaty is, in its present condition, not without gaps. The exact form of the proper names is difficult to establish.

INTRODUCTION OF THE EGYPTIAN SCRIBE.[a]

In the year 21,[b] on the 21st of the winter month (Tybi), under the majesty of the king of upper and lower Egypt, Ramses II.[c] It was on that day that his majesty was at the city "house of Ramses II," doing what his father Amen-Ra[d] approves. When there came the royal messenger and * * * and the royal messenger * * * (before the majesty of the king) Ramses II (with the messenger of Chatti Tar) tesob and * * * whom the great prince of Chatti, Chattusar, had sent to the Pharaoh to implore peace of the majesty of the king, Ramses II.

Copy of the silver tablet which the great prince of Chatti, Chattusar, caused to be brought to the Pharaoh by his messenger Tartesob and his messenger Ramses[d] to implore peace from the majesty of the king, Ramses II.

TRANSLATION OF THE ORIGINAL TABLET.[e]

Treaty, which was prepared upon a silver tablet by the great prince of Chatti, Chattusar, the mighty, son of Morsar, the great prince of Chatti, the mighty, grandson of Sapalulu, the great prince of Chatti, the mighty, for Ramses II, the great King of Egypt, the mighty, son of Seti I, the great King of Egypt, the mighty, grandson of Ramses I, the great King of Egypt, the mighty,[f] the beautiful treaty of peace and alliance, which establishes (between them beautiful) peace (and beautiful alliance) for all eternity.

REMEMBRANCE OF FORMER GOOD RELATIONS AND THE NECESSITY OF TREATIES.

Formerly, in very ancient times—as regards the relation of the great King of Egypt with the great prince of Chatti, the god did not allow any enmity to arise between them (and this happened) through a treaty. But at the time of Mutallu, the great prince of Chatti, my brother, he carried on war with (Ramses II) the great King of Egypt. Henceforth, however, from to-day on, behold, Chattusar, the great prince of Chatti (has caused to be drawn up) a treaty which determines the relation of the land of Egypt to the land of Chatti as Ra[g] created and as Sutech[g] created, that no enmity arise between them forever.

THE ALLIANCE IS CONCLUDED ANEW.

Behold, Chattusar, the great prince of Chatti, enters from to-day on into a treaty with Ramses II, the great King of Egypt, that it be a beautiful peace and a beautiful alliance between us in eternity. He is allied with me, he is in peace with me; I am allied with him, I am in peace with him forever.

After Mutallu, the great prince, my great brother, had followed his unhappy fate,[h] and Chattusar[i] sat upon the throne of his father as the great prince of Chatti—behold, I agreed with Ramses II, the great King of Egypt, that we (arrange) our

[a] The headings are not in the original, but are here inserted for convenience in reading.

[b] That is, of the reign of Ramses II.

[c] The bombastic and scarcely intelligible titles that follow here are omitted.

[d] An Egytian, as the name shows.

[e] The translation was made by the Egyptian so pedantically literal that in many respects he writes un-Egyptian. But in such passages the Babylonian of the original is the more transparent.

[f] All these titles of the Hittite, as well as of the Egyptian, are Babylonio-Assyrian, and not indigenous.

[g] Name of a god.

[h] The Egyptian rendered here the Babylonian expression literally. It means, to fulfill his fate; to die.

[i] Chattusar speaks here for a while in the third person of himself.

(?) peace and our (?) alliance. It is better than the peace and the alliance which existed before. Behold, (as) I, the great prince of Chatti, am in beautiful peace and beautiful alliance with Ramses II, the great King of Egypt, so shall the children's children of the great prince of Chatti be in alliance and peace with the children's children of Ramses II, the great King of Egypt. They shall be like us in a peace and alliance relation, and (the land of) Egypt (be) allied with the land of Chatti in peace, as we are, forever. No enmity may arise between them forever. The great prince of Chatti may never invade the land of Egypt, in order to rob it of anything, and Ramses, the great King of Egypt, may not forever invade the land of Chatti in order to rob it of anything.

ALLIANCE AGAINST ATTACKS FROM THE OUTSIDE.

The lawful (?) treaty which was in force at the time of Sapalulu, the great prince of Chatti, as also the lawful (?) treaty which was in force at the time of Mutallu,[a] the great prince of Chatti, my father, I firmly stand by. Behold, Ramses, too, the great King of Egypt, firmly stands by it (we both keep it) together, from to-day on we hold it firmly and act after this lawful (?) manner.

HITTITE AID FOR EGYPT.

If another enemy[b] goes to war against the lands of Ramses II, the great King of Egypt, and the latter writes to the great prince of Chatti: "Come to my assistance against him," the great prince of Chatti (will come to his assistance), and the great prince of Chatti will kill his enemy. But if the great prince of Chatti should not wish to set out himself, he will send his troops and his charioteers, and will slay his enemy.

ASSISTANCE AGAINST EGYPTIAN REBELS.

Or, if Ramses II, the great King of Egypt, is angry against * * * subjects, because (?) they have committed an offense (?) against him and he sets out to kill them, the great prince of Chatti will act in common with Ramses II, the Lord of Egypt.

EGYPTIAN ASSISTANCE FOR CHATTI.

In the same manner the great prince will act if another enemy sets out against the lands of the great prince of Chatti, * * * [What follows is mostly destroyed, but with corresponding changes it was similar to the above.]

ASSISTANCE AGAINST HITTITE REBELS.

But if subjects of the great prince of Chatti commit an offense against him, * * * [The same as above.]

TREATY OF EXTRADITION.

[The beginning is destroyed.] If nobles flee from Egypt and come to the countries of the great prince of Chatti, whether from a city (or from a country district [?]) of the countries of Ramses II, the great King of Egypt, and they come to the great prince of Chatti, he shall not receive them. The great prince of Chatti shall cause them to be brought back to Ramses II, the great King of Egypt, their lord.

Or when one or two people who are not prominent (?) flee from the country of Egypt and come into the Chatti land in order to become subjects of another, they will not be allowed to remain in the Chatti land, but will be brought back to Ramses, the great King of Egypt.

Or when a noble flees from the Chatti land [continues same as above, with corresponding changes].

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[a] An error of the Egyptian scribe for "Morsar."

[b] Doubtless awkwardly rendered by the Egyptian for "another one as enemy."

FORM OF OATH.

Of these words of the treaty of the great prince of Chatti with Ramses, the great King of Egypt, written upon a silver tablet, a thousand gods, male and female, of the Chatti land, together with a thousand gods, male and female, of those of Egypt, are witnesses. * * *

[Follows a list of the gods who shall watch as witnesses. Adjoining it is read:] Whosoever will not keep these words, which are written upon a silver tablet, for the land of Chatti and the land of Egypt, the thousand gods of the Chatti land, together with the thousand gods of the land of Egypt, shall punish him, his house, his land, and his subjects. But whosoever shall keep the words which are written upon the silver tablet and not neglect them, whether of the Hittites or of the Egyptians, the thousand gods of the Chatti land, together with the thousand gods of the land of Egypt, will preserve him in health and give him life, together with his offspring, his country, and his subjects.

POSTSCRIPT TO THE TREATY OF EXTRADITION—HOW TO RECONCILE WITH IT THE RIGHT OF ASYLUM.

If one, or two, or three people flee from the land of Egypt and come to the great prince of Chatti, the great prince of Chatti shall have them seized and returned to Ramses, the great King of Egypt. No accusation shall be made against the man who is thus brought to Ramses on account of his offense; his house, his wives, or children shall not be punished; he shall not be killed, nor shall his eyes, his ears, his mouth, or his feet be mutilated; in short, no charge whatever shall be made against him on account of his offense.

In the same way, if one, or two, or three people have fled from the land of Chatti * * * [The same as above, with corresponding changes.]

DESCRIPTION OF THE SILVER TABLET.

On the obverse of the tablet is shown a figure of Sutech,[a] who embraces the figure of the great prince of Chatti, surrounded with an inscription which says: "Seal of Sutech, the King of Heaven, seal of the treaty which Chattusar, the great prince of Chatti, the mighty, son of Morsar, the great prince of Chatti, the mighty, concludes." Within the bordering of the sculpture is the seal * * * (supply, "of the great goddess?").

On the reverse is a sculpture, a figure of * * * (supply, "the great goddess?") of Chatti, who embraces the figure of the great princess of Chatti, surrounded with an inscription which says: "Seal of the sun god of the city of Arenena, the lord of the earth, (and?) seal of Rutuchipa, the princess of the Chatti land, daughter of the country of Kizawaden, the (lady?) of the city of Arenena, the lady of the land, the worshiper of the god(?)." Within the bordering of the sculpture is the seal of the sun god of Arenena, the lord of all lands.

This treaty of alliance and extradition is, accordingly, the renewal of a former one, one party to which was Sapalulu, the grandfather of King Chattusar.

Subsequently the Kingdom of Chatti goes rapidly to ruin, partly through the inrush of a wave of Aramean peoples, partly through the advance of new Hittite peoples from the north and northwest, with whom, already in 1100 B. C., Tiglath-Pileser I came in conflict,

[a] By Sutech the Egyptian renders the names of all foreign gods. It is not the name of a Hittite god.

although Carchemish (Jerabis) on the Euphrates (west of Carrhar), a Chatti state, for a couple of centuries keeps up the appearance of independence by the ready payment of tribute to the suzerain of the time until in 717 that region also became an Assyrian province.

Another stratum of the Hittite peoples is met with during the fifteenth century in western Asia Minor in the Lukki, who, according to the Tell-Amarna letters, carried on piracy on the southern coast of the Peninsula and as far as Cyprus. The provinces of Lycia and and Lycaonia are named after them, and we assume that they overran the whole of western Asia Minor.

A couple of centuries later we see new Hittite peoples advance and, availing themselves of a period of weakness of Assyria, settle in northern Mesopotamia on the Euphrates. They were the Kummuch, who gave their name to the later province of Commagene. Tiglath-Pileser I (see above) joins with them in battle in 1100 B. C. on the Euphrates and subjugates them, but at the same time on the borders of the Kummuch meets other peoples of the same race, the Muski, who were not yet permanently settled, but still advancing, and farther back he meets the Kaski and Tabal. He repulses them. The Muski very probably retreated back of the Halys and settled there, for in 700 B. C. their name is employed as an old historical territorial designation of a new kingdom, which was of the same character and extent, but Indo-German. King Midas of Phrygia is called in the Assyrian inscriptions "Mita of Muski." The Tabal settle in Cappadocia, the Kaski north of it in Armenia Minor. In addition to these are also mentioned the Kumani, who occupied the mountains of the province of Melitene and have given Comana its name.

A little later we meet another branch of the Hittite group in the Chilakku as heirs of the Lukki. The Assyrians came across them in Cappadocia, though their name remained attached only to Cilicia, the country south of the Taurus.

All the peoples above mentioned maintained for centuries a constantly changing attitude toward Assyria. Whenever the Assyrian armies were far away, or Assyria was weakened through external or internal upheavals, they withheld allegiance and stopped paying tribute, but at the approach of the Assyrian armies they immediately again sent tribute and declared their submission. Tired of this constant change, the Assyrians at last embodied a part of these peoples as provinces into their empire, Carchemish, in 717 B. C. (see above); Tabal, with Chilakku and Kur (with the capital Tarsus), that is, Cappadocia and Cilicia, under Sargon (722–705 B. C.); then Kommanu (with Comana) as the province of Tulzarimmu in 712 B. C.

The last shoots of Hittite state organization are most probably to be looked for in the Lydian and Cilician Kingdoms.

Soon after 700 B. C. the Indo-German Kingdom of Midas of Phrygia, disappeared through the shock of the Cymbrian immigration. The Lydian Gyges, perhaps a liege man of Midas, took advantage of the confusion to establish upon the ruins of the Phrygian Kingdom, as successor to its power, a Lydian Kingdom, which again was most probably Hittite. East of it, in Cappadocia and Cilicia, we see during the last years of the Assyrian Empire, from about 660 B. C. down, the gradual formation of a new Kingdom of Chilakku (= Cilicia, but extending much farther north than the later province), which soon after the fall of Nineveh, in 606 B. C., appears under Syennesis, at the time of Nebuchadnezzar, as the fourth great power of the Orient alongside of Lydia, Media, and Babylonia, and together with Nebuchadnezzar mediates, in 585 B. C., the peace between Alyattes of Lydia and Kyaxares of Media. Judging from the names of the kings, we should also consider this Kingdom of Chilakku as Hittite. It was only the conquest of Asia Minor by the Persians under Cyrus that put an end to this and to the Lydian Kingdoms, and thus also to the last Hittite state formations on a large scale.

This is the development on the western stage. But we also meet Hittite States farther east in Armenia. Shalmaneser I (in 1275 B.C.) and Tiglath-Pileser I (in 1100 B. C.) came across a series of peoples in the mountains of Armenia, west and south of Lake Van, which we must consider as Hittites, since the Kummuch (see above) are among them, and agreements in the names also support this assumption. At first we meet here a series of isolated tribes. From 850 B.C., however, probably in consequence of new immigrations, a great empire is being formed around Lake Van, which for two centuries was a dangerous rival of Assyria. The Assyrians call it Urartu, the native inscriptions Biaina. Its center is the city of Thuspa (modern Van) on the eastern coast of Lake Van. In the times of its greatest power it extended from the Araxes to Melitene, Syria, and southeast to Lake Urmia. Its power, broken by Sargon, was annihilated through the Indo-Germanic immigration in the seventh century B. C.

As meager as is our acquaintance with the history of the Hittite peoples, so also is our knowledge of their civilization, for accurate knowledge results almost exclusively from comprehensive and careful excavations. But as regards the territory under consideration, excavations by the German Orient committee have been made only at Senjirli, in North Syria, a few days' journey from the Bay of Iskenderun. The English have made excavations east of the point mentioned, at Carchemish (at present Jerabis) on the Euphrates, and the French at Boghazkeu and Ueynek, in the interior of Asia Minor, in Cappadocia, while excavations have been made by the English, Germans, and natives in Armenia, on the eastern coast of Lake Van. What other monuments of Hittite civilization have become known to

us have been found either on or near the surface, or may still be seen on the rocky walls of Asia Minor. Special mention should be made of two finds in the ruins of Babylon—a stone bowl and a stone image of the Hittite storm god—the latter on the occasion of the present excavations of the German Orient Society—as also of one in the ruins of Nineveh, because they were found at such a distance from the settlements of the Hittites, and must have come there through contact either in war or in peace. At Nineveh there came to light eight small pieces of clay on which seals were impressed with Hittite characters, serving to verify some documents or other objects to which they were attached by means of cords.

The sites of the finds of the monuments extend over entire Asia Minor as far as Smyrna and over North Syria and Armenia, but are most abundant around the Bay of Iskenderun, in Cappadocia, Cilicia, and North Syria. Although the number of the products of civilization from all these places can not be termed inconsiderable, and is, moreover, increasing with each year, the circumstances mentioned above, that they were all discovered casually on the surface of the earth and that the accompanying inscriptions are still unintelligible, makes it, as yet, impossible to assign the monuments—with the exception of the Armenian finds—to the single peoples which meet us in history, to fix them in time or to construe a history of the development of Hittite civilization and art. It would also be unwise to represent the undeniably existing points of contact with the Egyptian and Assyrian art monuments as loans on the part of the Hittites. A description of the Hittite civilization must for a long time be limited to the presentation of facts.

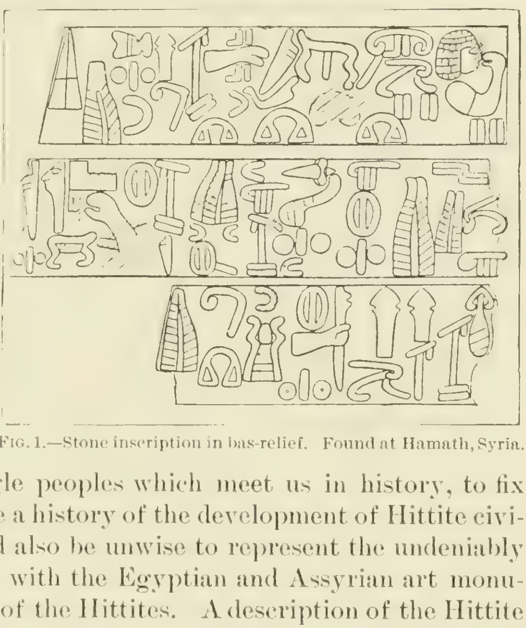

FIG. 1.—Stone inscription in bas-relief. Found at Hamath, Syria.

The writing of the Hittites[a] (see fig. 1) is pictorial script. It shows human and animal heads; also whole animals, such as hares and birds; then hands, feet, and claws, besides a large number of images of objects, of which only a few, such as the sword, are as yet intelligible. While on the probably older inscriptions these pictures are executed in detail, the more recent ones exhibit a transformation of

[a] To obviate misunderstandings, it may be explicitly pointed out that in the following, if the contrary is not expressly stated, the entire group of peoples, not the single population, is meant.

many of them into simpler, more conventional forms by merely outlining them. With this is combined another mark of progress. The signs of the older inscriptions are cut in relief; whether there are exceptions to this custom can not be determined with certainty. Those of the more recent are intaglio. This grouping of some inscriptions as older, others as more recent, can not yet be supported by their contents, but is based upon the following peculiarity: A close study of the inscriptions shows that the direction faced by the signs (notice especially the faces) varies. In figure 1, line 1, the face is turned toward the right; in line 2, on the other hand, toward the left. Since, according to the process of the Egyptian hieroglyphic inscriptions and the unmistakable indications of the Hittite inscriptions themselves, the writing is always to be read in the direction of the faces, it follows that line 1 runs from right to left, line 2 from left to right, and line 3 again from right to left. The inscription terminates with two-thirds of line 3, and the fact that the left third, not the right, remains blank shows that our arrangement is correct. Within the lines there stand several signs below one another which are to be arranged from top to bottom. Those inscriptions which by reason of the form of the characters had been above designated as the older ones, with a few exceptions resulting probably from special circumstances, always begin on the right-hand top and strictly maintain this direction throughout. On the other hand, in many of the inscriptions which, on account of the cursive form of their signs are estimated to be of a later period, it can be observed not only that they begin on the left-hand top, but also that some signs no longer follow the right direction demanded by the course of the lines. This may probably be accounted for by the lack of practice in the use of picture writing, caused by the fact that in daily life, as in Assyria and Babylonia, another simpler system—perhaps the Aramaic phonetic writing—was already employed. In addition, it should be noted that the later an inscription appears to be by other indications the more apparent becomes the division of the words by definite punctuation marks. There had probably already arisen the need of punctuation marks to facilitate the reading and arrangement, just as in the case of an Egyptian, who wished to learn the cuneiform writing, divided up the words with red lines on the clay tablet which he was studying. (See Der alte Orient, vol. I, pt. 2, 2d ed., p. 5.)

There have so far been found about 35 larger inscriptions, and to these may be added a great number of inscriptional fragments and of short inscriptions on seals, etc. Besides, hardly a year passes without new inscriptions coming to light. It can, therefore, be easily imagined that the desire to know what these inscriptions contain becomes more and more lively. But all efforts to decipher them made since 1870, when the inscriptions of this sort for the first time aroused

close attention, have been in vain. The cause of failure is the meager or indefinite information concerning the Hittites on the part of their neighbors or successors, and the puzzling complications of their system of writing. It is approximately estimated that there are already known more than 200 signs in their system, and this number is increasing with each new inscription. As far as can be inferred from the inscriptions and from other writing systems of western Asia, some single signs stand for entire words which in reading are either to be pronounced, or are merely explanatory, to indicate the notional sphere into which a preceding or following written-out word belongs;[a] some denote a syllable, others again merely a sound. The mingling of all these signs naturally renders the system very obscure, since one and the same word can be written in an entirely different manner. In the uniform writing systems of the Egyptians and Babylonians, inscriptions which presented the same content in different parallel scripts and languages, one of which was known or easy to make out, smoothed the difficulty of decipherment. It is true that we have also for the Hittite writing system such an example, which naturally has been much discussed. It is the bilingual inscription of "Tarkudimme" (fig. 2). But, unfortunately, it is too short and presents in itself too many riddles to be of any use. The object made of silver, in form something like a hollow hemisphere, formed the upper part of a dagger handle and was to serve as a seal. The convex surface is engraved with a figure and writing. On the edge runs a cuneiform inscription reading: "Tarkudimme, King of the country of Erme (? or Me ?)." In the center, to the right and the left of the figure of the King, is a Hittite inscription twice repeated. The distribution of the content of the cuneiform script over these six signs presents so many difficulties that one is compelled to suppose that the Hittite inscription either contains only a portion of it or something entirely different.

FIG. 2.—Inscription of the Tarkudemos Bors.

The Hittite hieroglyphic writing has become the parent of a series of partly alphabetical writing systems which in later times meet us on the soil of Asia Minor. To these belongs the script used on the isle of Cyprus, a syllabic writing, where nearly every sign denotes a syllable (consonant and vowel). A large number of Greek inscrip-

[a] Such a sign is that for "God"—consisting of an oval with a crossbar in it—the only one thus far interpreted with certainty without, however, knowing how it is to be pronounced. The first sign in figure 1—a head with an arm and the hand pointing to the face—which stands at the commencement of many inscriptions, very probably means "I am," or (N N . . .) "speaks." But here, too, the pronunciation is unknown.

tions are written in this script. The fact that such complicated script was employed alongside of the Greek attests to the great predominance of pre-Grecian civilization in Cyprus. The Lycian, Carian, Pamphylian, and other scripts of Asia also trace back, at least in part, to the Hittite.

Although the hieroglyphic inscriptions are thus still unintelligible to us, we have some examples of the Hittite dialects in Babylonian script. Among the clay tablets of Tell el-Amarna (see Der Alte Orient, vol. I, pt. 2) are found a couple of letters in cuneiform writing, but in Hittite language, of the Kings Tushratta, of Mitani, North Mesopotamia (ibid., vol. I, pt. 2, 2d ed., p. 14), and Tarchundaraba, of Arsapi or Arzawa (ibid., p. 5). Clay tablets in the same language were found at Boghazkeu, in Cappadocia. The largest number of monuments, however, was furnished by the soil of Armenia. There were discovered numerous rock inscriptions, of historical and religious content, which in the characters of cuneiform script speak to us in the language of the ancient Hittite people. They are usually designated after the capital of this people, Van, as the Van inscriptions. Of this language, as also of the Mitani language, which is clearly related to it, we already understand something, so that the documents can in part be translated. But we do not gain by that a clear idea of the structure of these languages, nor are we in condition to affirm with certainty a relationship with other known languages. Still, there seems to be these points of contact with the languages spoken in the Caucasus, especially with the Georgian.

The personal appearance of the Hittites on their monuments is very peculiar, even if allowance be made for what may be lack of skill in the representation. Anthropological investigations, such as measurements of the skulls of the present inhabitants of western Asia, in whose midst remnants of older races can be discerned, have made it probable that the Hittites, the modern Armenians, and a part of the Jews[a] belong to one and the same race. Their characteristics are strikingly short heads (bracychphaly), dark eyes and hair, and large curved noses. The latter is most conspicuous on the monuments. The Egyptian representations depict the Hittites with oblong, slightly curved noses, strongly receding foreheads, prominent cheek bones, beardless, with short, round chins, and with fair skin. The hair is long and thick and fails upon the shoulders in two strings. On the Hittite monuments only one queue, and that braided, is seen, and, besides, a large number of the men wear beards. The arrangement of the hair of the women is the same as that of the men.

[a] Which is, accordingly, not Semitic by race, though having a Semitic language. Race affinity and linguistic affiliation do not coincide. The true Semitic type is, according to the same investigations, preserved among the Bedouins in the desert, and is characterized as dolichocephalic.

FIG. 1.—HITTITE REPRESENTATION OF A MEAL. SENJIRLI.

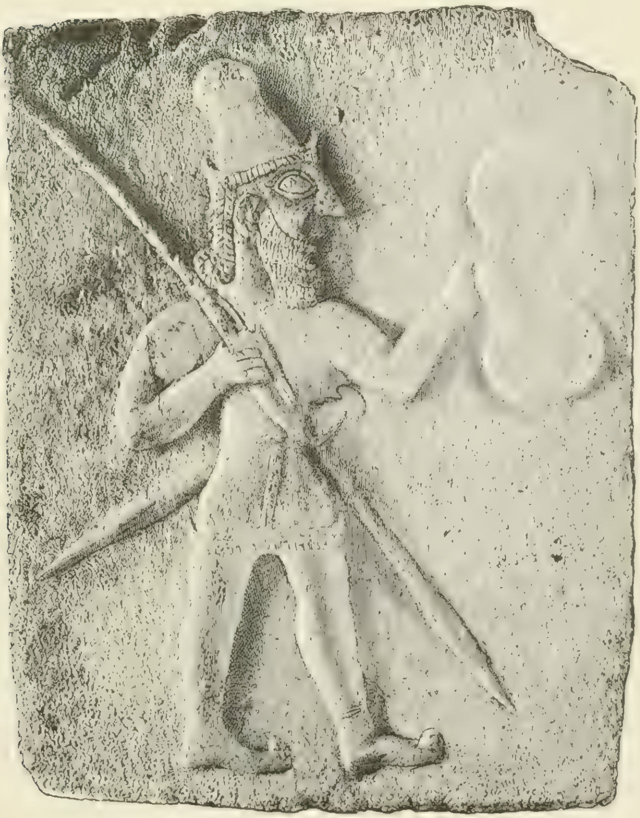

FIG. 2.—HITTITE WARRIOR. FROM SENJIRLI, 1888.

FIG. 1.—DIVINITY EMBRACING A KING OR PRIEST. BOGHAZKENI.

FIG. 2.—DIVINITY WITH HEAD GEAR DECORATED WITH HORNS. FOUND IN JERABIS (ANCIENT CARCHEMISH).

FIG. 3.—RELIGIOUS SCENE. BOGHAZKENI.

The dress of the men consists chiefly of a coat with short sleeves reaching to the middle of the upper arm, closed around the neck, and reaching only to something above the knees, the lower edge being frequently lined with fringes or a thick border. It is held together, around the hips, by a broad belt beneath which there is indicated a slit, slantingly running downward. Whether and how the legs were clothed can not be definitely determined from the reliefs. In place of this short coat there is less frequently found a long one, reaching to the feet, likewise with short sleeves, closed around the neck and girdled about the hips. Sometimes the belt seems to run, in an unexplainable way, partly under, partly over the coat. This dress is common to men and women. With the latter it seems sometimes to fall down underneath the belt in perpendicular folds. In a few cases it is lined with points and fringes. Distinguished from it is a long cloak which evidently is worn over the short coat described above, as it seems, only by persons of importance priests or kings. It apparently consisted of a long piece of cloth thrown over one shoulder and drawn around the chest so as to form a fold for one arm while leaving the other free and falling down on the back. From the representations it is supposed that this garment was made of artistic textures. The dress of the women, described above, was sometimes supplemented by a piece of cloth thrown over it, which can hardly be anything else than a veil. It was in some manner fastened to the head gear, falling over it to the feet and covering the entire back. The edge of the veil is ornamented with fringes.

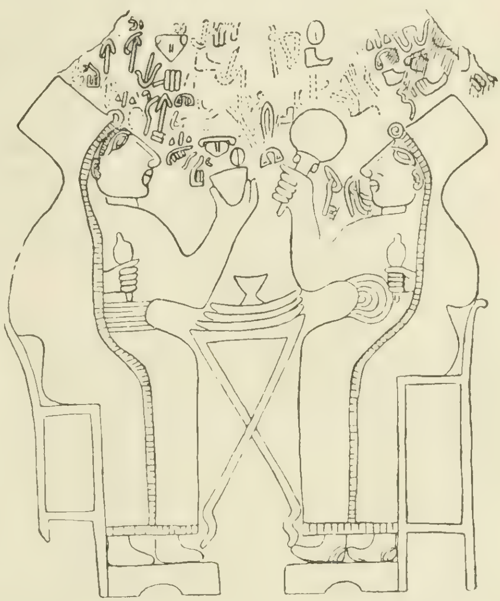

FIG. 3.—Sepulchral monument, found at Marash, North Syria.

The head gear of the men is generally a pointed hat, probably of felt or leather and of cone shape. At the lower edge is a rim turned upward. Occasionally it is decorated with perpendicular stripes, not satisfactorily explained, and sometimes also with circular ornaments. A variety of this pointed hat is one that terminates in the form of a ball. Quite peculiar is the head gear of the women, consisting of a

kind of cylinder. While it usually has a rim bent upward and is without ornaments, those on the reliefs of Boghazkeu exhibit perpendicular stripes, are notched at the top and lack the rim. In this form it is the starting point for the head gear of later representations of the goddess Cybele, termed the "mural crown." A head gear common to both sexes is a round, closely fitting cap, sometimes ornamented with perpendicular stripes, horizontal rows of rosettes, or with small rosette-shaped settings on the front which perhaps consisted of precious stones. In isolated cases there is also found, as head gear for men, a cap with a tassel, just like the modern Turkish fez.

The foot gear of the Hittites is a shoe with turned-up tips. It is found among many mountain inhabitants, as the turned-up point protects the toes better than the straight shoe. In several cases the figures wear sandals, consisting of a flat piece of leather held by thongs under the foot, the heel being provided with a cap for better protection.

Few ornaments can be discerned upon the monuments. Wrists and ankles are occasionally adorned with rings. Earrings frequently occur as ornaments also of men. In one case a necklace is seen on a woman. Women are usually represented with a mirror in one hand, while the other hand holds either an object required by the situation portrayed or something resembling a pomegranate or a spindle. The men carry a staff as a mark of dignity. The priestly or royal mark of special dignity seems to have been the crook, carried with the curved end downward.

The army of the Hittites was composed of foot soldiers and charioteers, horsemen being of rare occurrence on the reliefs. The foot soldiers wear, as far as can be ascertained, a short coat, pointed cap, and boots. The chief arms are bows and arrows. By their side are also seen a long lance, club, double-edged axe, single and double edged sword, and a sickle-shaped sword. The handle of the common sword terminates at the upper end in a globular knob. On the native monuments no helmet can be recognized. But the Egyptian representations of Hittite nobles and charioteers exhibit a low morion, round on the top, with a hair tuft. The shield is either quadrangular or of the form of the so-called Pontian Amazon shield, approaching the outline of an 8. The war chariot is a low box, open in the rear, resting upon two wheels, and drawn by two horses. On each side is a quiver, while the rear part holds the lance. The Egyptians emphasize the fact that each Hittite chariot had three warriors—the charioteer, the shield-bearer, and the bowman, because it differed from their own custom. Upon the Hittite representations the shield-bearer is lacking. This, however, is accounted for by the circumstance that they all depict hunting and not war scenes.

FIG. 1.—HITTITE GOD OF THE CHASE, HOLDING HARES. SENJIRLI, ASIA MINOR.

FIG. 2.—HITTITE KING, WITH SCEPTER AND SPEAR. SENJIRLI, ASIA MINOR.

FIG. 3.—HITTITE WINGED DIVINITY, WITH HEAD OF GRIFFON. SENJIRLI, ASIA MINOR.

Originals in Royal Museum, Berlin.

FIG. 1.—STORM GOD TESHUP. FROM BABYLON.

FIG. 2.—HITTITE STORM GOD, WITH HAMMER AND LIGHTNING.

FIG. 3.—HITTITE WARRIOR, WITH AX AND SWORD. SENJIRLI, ASIA MINOR.

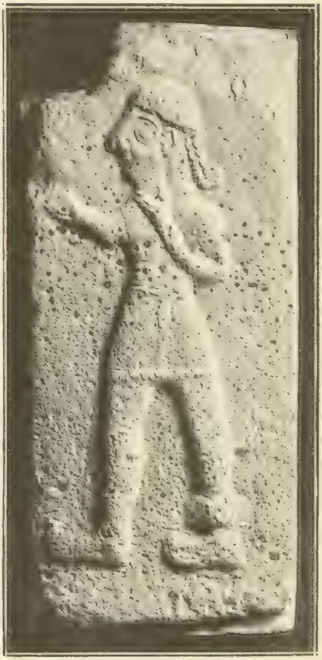

FIG. 4.—HITTITE SUPPLIANT. BOGHAZKENI, ASIA MINOR.

Originals in Royal Museum, Berlin.

The war chariot was also employed for the chase. The animals hunted are represented as the lion, the deer, and the hare. The first was chased with dogs. On one of the gate slabs of Senjirli the god of the chase is represented with human body and the head of a lion. He holds in one hand a hare, in the other a boomerang, which, accordingly, must have been used in hunting. On each of his shoulders is a bird, evidently a falcon, which already in ancient time was trained for the chase.

This peculiar god image, a mixture of man and beast, leads to a consideration of the religion of the Hittites. Here, too, the meagerness and obscurity of tradition, and the failure to decipher the inscriptions is to be regretted. Only scattered details can, therefore, be culled. With which of the Hittite peoples originated the names of the gods in Asia Minor which the Greeks transmitted, and whether their form is the correct one, can not yet be determined. More reliable, but scanty, is the information of the cuneiform inscriptions. Some knowledge can also be derived from personal names, as in the Orient they are frequently composed with the names of gods. The pictorial representations also teach us to a certain extent concerning the nature of the gods.

Everywhere in Asia Minor and northern Syria tradition places in the foreground the worship of a goddess which is sometimes designated as the "great mother." At Komana in Cappadocia she was worshiped under the name of Ma. She wears upon the head the so-called mural crown. Innumerable priests and priestesses served her. The latter were called Amazons, and from the Greek legends are known as warlike priestesses. The former, who were eunuchs, bear the name of Galls, and constitute a peculiarity of Asia Minor cult. (Comp. Der alte Orient, vol. III, part 213, 2d ed., p. 61, note 1.) The festivals of the goddess, to which large multitudes are said to have flocked, were celebrated with wild songs and dances accompanied by noisy music, the priests on such occasions being thrown into such a frenzy as to emasculate themselves. To be sure, this is related of the cult of the great goddess at Hieropolis-Bambyke in northern Syria, but this is the same goddess, even though she bears another name. She is called Semiramis. Her sacred animal is the dove. In this connection it is worthy of notice that the name-group of this goddess, distinctly recognized in the pictorial inscriptions, though it can not yet be read, contains the image of a bird. For an understanding of the legend of her killing each of her lovers in succession reference may be made to the man-hating Ishtar, and the legend of her concealing her sex suggests the bearded Venus of classical antiquity. (Der alte Orient, *ibid.*, pp. 61 to 63.) Besides this goddess are mentioned Dionysos and an unspecified god who doubtless corresponds to her beloved, Adonis-Tamuz (*ibid.*, pp. 61, 62), as yearly a pyre is erected and a

dirge recited in his honor. For Lydia we have the names Heracles or Sandon and Omphale transmitted, they are the sun and moon gods. The former is said to have been worshiped also in Cilicia under the name of Sandon. The chief act in his cult there is said to have been the erecting of a pyre (see above). In addition to Ma and Semiramis the name of Cybele is also found for the "great mother," especially in Phrygia. Like Ma she also wears upon her head the mural crown. Combined with her is Attis, her beloved, corresponding to Adonis-Tamuz. Rhea, another form of the great mother, was attended by the Dactyles or deities considered as the inventors of metallurgy. As the moon god worshiped in Asia Minor, the name Men is transmitted to us.

From the cuneiform inscriptions and from the personal names it can be concluded that among the western Hittites, the god at the head of their pantheon bore the name Tarku, while among the eastern Hittites it was the storm god Teshup. Both names, but especially the latter, are of comparatively frequent occurrence. Teshup is represented (pl. IV), at least on the soil of northern Syria, as a warrior, holding in one hand a bundle of three lightning forks, with the other swinging the hammer, the symbol of fertility. (Compare Tor with the hammer Mioelnir.) In Cilicia a god Sanda, among others, was worshiped. Among the Mitani we meet besides Teshup, the goddess Shaushkas, corresponding to the Babylonian Ishtar, and perhaps a god Shimigi. The so-called Van inscriptions (see p. 692) contain a large number of names of gods, but we are little informed concerning the nature of most of these deities. The god Teshup was probably received by the people of the Van inscriptions from an earlier people belonging, however, to the same race, for though he is often mentioned in their inscriptions, the first place is held by the god Chaldis, who is scarcely wanting in any of the incriptions. We also frequently meet with a triad of gods as the most important ones, Chaldis and the storm god Teshup or, as he is called is this dialect, Teïshebas being joined by the sun god Ardis. Rarely is the moon god Shelardis mentioned. Concerning the sacrifices to be offered to the gods on various occasions the inscriptions contain detailed statements which, however, are not yet fully intelligible.

The monuments themselves present a series of religious scenes, the most important being found at Boghazkeu (probably the ancient Pteria) in Cappadocia. The living rock forms there in one place, in a general manner, a rectangular room, without ceiling, one broadside of which, open in its entire width, forms the entrance. The stone walls in the interior are perpendicular. On these walls a large religious scene is sculptured composed of about 70 persons advancing one behind the other. Upon the rear wall, facing the entrance, is the principal group (pl. II) forming the center of the whole. Toward

FIG. 1.—HITTITE LION CHASE. SAKTCHEGÖZN.

FIG. 2.—HITTITE WARRIORS. BOGHAZKENI, ASIA MINOR.

Originals in Royal Museum, Berlin.

FIG. 1.—HITTITE WINGED SPHINX, WITH DOUBLE HEAD OF MAN AND LION.

FIG. 2.—HITTITE WINGED SPHINX, WITH HUMAN HEAD.

Originals from Senjirli, Asia Minor, in Royal Museum, Berlin.

it advance from the left side wall a procession almost exclusively of male figures, one behind the other, and in the same manner from the right side wall one of female figures. The persons represented on the rear wall who stand partly upon mountains, partly upon human figures, partly upon animals, are doubtless to be considered as divinities. The god at the head of the male procession who stands upon the heads of two persons, probably priests, and has by his side an animal with a pointed cap upon its head, is represented as a warrior. He turns with outstretched hand toward a goddess advancing from the opposite direction who stands, with a mural crown upon her head, upon a panther and has likewise by her side an animal with a pointed cap. Behind her is a god standing upon a panther, the only male in the female procession. We therefore see in him the "beloved" of the great goddess. The entire scene has received the most divergent interpretations, the most probable of which sees in it a representation of the spring myth, though the interpretation does not solve all the difficulties. The meeting of the sun god and the moon goddess—for this is the likely interpretation of these divinities—each at the head of a solemn train, seems to symbolize the vernal constellation of sun and moon. The male procession on the left side ends with twelve perfectly identical personages who carry sickle-shaped swords and seem to advance in a kind of trot. In this may be seen a representation of the dancing with arms by the priests which is said to have taken place in the festivals of Ma. Many of the figures have in front and above their heads groups of hieroglyphics that evidently contain names of gods and establish the sculptures as Hittite.

Upon a rock wall, near the one just described, is found the relief of pl. II. The representation, besides being absolutely unique in itself, attains a special value from the circumstance that a short explanation of it is preserved to us from antiquity itself in the description of the seal of the chief Hittite god, given at the conclusion of the Hittite treaty (see p. 686). Our relief evidently exhibits the same representation as that of the seal: The god, represented as a warrior in heroic size, embraces a Hittite prince or priest. The name of the god is unknown, as the Egyptian has inserted the name of the Egyptian Sutech in place of the Hittite. The agreement of the relief with the inscription is important, also, for the reason that it enables an approximate dating of the Boghazkeu sculptures, which some would refer as far back as 700 B. C. But as this unique representation is thus far met with only twice, the tendency is to combine both cases of its occurrence, i. e., to refer them to about the thirteenth century, the time of the Hittite treaty, although it must be admitted that the artistic execution seems to favor a later date. But as we know as yet almost nothing of the art development of the Hittites, this circumstance must not be given too much importance.

At Fraktin, in Cappadocia, south of Cæsarea, a Hittite sacrificial scene is represented upon a rock. To the left stands a god in the garb of a warrior, holding in one hand a crook over his shoulder. Before him is an altar, which in its ground form is a pillar, somewhat tapering upward, with a thick plate placed horizontally over it. Before it stands a man, perhaps a priest, in the dress of a warrior, turned toward the god and with his right hand pouring a libation from a vessel. To the right is another identical scene, only that here a priestess in long dress offers the libation to a seated goddess. Upon the altar here a bird is sitting. This is worthy of notice. The type of a seated goddess with a mirror or flower in the hands and occasionally a bird sitting upon the altar or upon a table before her, meets us often on the Hittite sculptures. We may safely recognize in it Semiramis, to whom the dove was sacred, or, as she is also named, Ma of Comana, etc. At Irviz, on the border of Cilicia and Cappadocia, there is seen upon a rock in a lovely and fertile region a king or priest in adoration before a god of fertility. The god is marked as such by having in one hand a vine with many clusters, in the other a cornucopia from which water is streaming.

As unique creatures of religious fancy may be mentioned the sphinxes and gryphons. The former are fantastic beings with lion bodies and human heads, and generally winged. Upon one relief the sphinx is given even two heads, one of a lion in natural position and the other of a man placed perpendicularly upon the neck. The gryphon has the body of a man, but the head of a vulture, and also has wings.

The examples of Hittite architecture remain for the most part still buried. Only in one place, at Senjirli, North Syria, have extensive excavations been made, to be described in a future publication, uncovering the site of an ancient city. The city was surrounded by a double, nearly circular, wall protected by towers. Within this large circle was the citadel proper, raised upon an elevated site. It was inclosed by a second wall, likewise provided with projecting towers, and on the south side was a large gate of a characteristic plan, for the wall was not merely cut through to effect an opening, but considerably thickened at the gate, so that it has two passages, in front and in the rear. The space between the passage within the wall on both sides is partly unfilled, so that a large quadrangular court is formed. On either side of the outer door large towers project. All the walls are of extraordinary thickness, even several meters thick, and consist, in the lower portion of uncut stones, to keep off moisture, and the upper part is of unburnt bricks. Clay is employed as building material through the entire Hither Asia, even where other material is available, and the custom dates back to Babylonian influence. The inner walls of the gate and palace rooms were faced with stone slabs,

1 to $1\frac{1}{2}$ meters in height, adorned with reliefs. The edifice in its simplest form was of a quadrangular ground plan with colossal walls and had varied chambers. The front showed two large towers, which, however, were not an organic part of the building. Between them an open vestibule with columns formed the entrance, to which a few steps led up. The columns must have been of wood, as nothing is left of them excepting the stone bases, which were formed of single or pairs of sphinxes.

A gate very similar to that of Senjirli was found at the village of Veynek, in Cappadocia. Part of the large stone slabs used as wall dressing, upon which are representations of sacrificial scenes, as also two large sphinxes which flanked the gate passage, are still in place. At Boghazkeu, also, numerous wall remnants of an extensive ancient city are found. In the northern part of it are still discerned the foundation walls of a large palace of quadrangular ground plan, with many rooms. The walls are preserved to the height of about a meter, and consist, like those of Senjirli, of rough, uncut stones. From this circumstance it may be inferred that here, too, the upper part of the wall consisted of unburnt bricks. To the excavations at Jerabis, on the Euphrates, on the site of the ancient and oft-mentioned Carchemish, we owe our knowledge of the wall slabs with reliefs, which until now represent the high-water mark of Hittite artistic development in sculpture (see pl. II), in which, however, Assyrian influence is distinctly discernible. It shows itself in the position and carriage of the figures and in the care applied to the reproduction of ornamental details. Worthy of notice is the remarkably high relief employed in some of the Jerabis sculptures. The reliefs, accompanied by inscriptions, evidently form the decoration of the entrance to a Hittite palace.

The subjects of the Hittite sculptors, so far as can be understood, are chiefly religious, and have been largely referred to above, but special mention may be made of a unique work upon a rock at Boghazkeu. It has a human head with a pointed cap upon it, while the entire body is composed of four lions. Of two of them only the fore parts are represented; they form the breast. Their bodies, to the right and the left, are turned outward, and appear at a distance like arm stumps. The two other lions represented in full are bent with their heads downward and turn their backs to the right and the left outward. They represent the body of the figure. In place of legs, which are not indicated, there are perpendicular straight lines, which unite at the bottom. The frequently occurring double eagle (fig. 3, pl. II) is also remarkable as a second instance of the composition of fantastic figures of animals, but especially because it forms a directly connecting link between modern times and Hittite antiquity, for the Austrian double eagle is borrowed from the latter. It was first

adopted in the Orient by the Seljuk sultans (in 1217 A. D.), and from them descended through the German emperors, its first appearance on their coat of arms being in 1345.

Among nonreligious sculptures, tombstones will first be mentioned. Fig. 3, page 693, and probably fig. 1, pl. I, are such representations. They are stone slabs of human size, provided at the bottom with a stone peg to fit into a socket to keep it in an upright position. Upon the fore side the dead is invariably represented sitting at a meal, alone or with another person. Before him or, in the latter case, between them, is seen a table with crossed legs, resembling our camp stools, upon which food and drink are set. Fig. 3 shows two women, each holding in one hand a pomegranate (or a spindle?), while in the other hand one woman has a mirror, the other woman a bowl which she carries to the mouth. Besides these we have the lower parts of two human statues, provided with inscriptions. The execution is very stiff and shows only feeble attempts at reproducing the folds of the drapery. Of animals, the lion is most frequently represented. Head and chest stand out free from the stone slab, while the body is merely in relief, as the work was for a gate ornament, and had to be represented with one half of the body fitted into the wall.

Regarding the character of the Hittite sculptures, that is, those thus far known, they must be considered as rude, childish, and stiff, though improvements and efforts to enliven the figures can not be denied. As we are not able to read the inscriptions on the sculpture no date can be assigned to the work, and we are therefore unable to describe the historical development of Hittite art. A conclusion from purely artistic view points, considering the manifold circumstances which influence civilized life, would easily lead astray. Thus sculptures found in two different places, some of which may be very rude, while others point to a considerably higher degree of art, may belong to the same period. The explanation of this would be that the former decorated the palace of a petty unimportant prince without the means to engage the best artists of his time, while the latter come from a contemporaneous, but powerful and rich ruler. Only when productions of different art degrees are found in the same place is a chronological arrangement of them to a certain extent justified. This is the case at Senjirli. Here were found at the southern gate of the city wall sculptures which are certainly older than those of the southern gate of the citadel wall. But the material is too meager for establishing a development in detail.

Most of the sculptures are executed in low relief. In the crudest the representation is a simple outline, within which muscles, drapery folds, and other details are merely indicated by awkwardly incised lines, so that the legs or wings of animals sometimes appear as merely mechanically attached to the body. This line drawing betrays metal

work as the starting point of stone sculpture, for figures in metal are driven from the back of the plate to the front, and the muscles and other details are then indicated by reversing the process in the respective parts of the metal. The writing of the Hittites also indicates such origin for their art, the oldest inscriptions showing the characters cut in relief, which is much more difficult than intaglio work to produce in stone.

The primitive sculptures also show an utter lack of proportion. The lower part of the human body is usually much too small in proportion to the upper part, or the arms are two thin and too short. Animal bodies are either excessively drawn out or are shortened. But while these faults are less evident in the better sculptures, there is common to all an almost entire absence of perspective. Of objects with some depth only the fore side is represented. Thus in fig. 3 and pl. I, table and chairs seem to have only two legs each, and the plate of the former is merely a line. The toes on the feet of human figures and the claws of lions are generally piled one upon another instead of being entirely or partly spread out, while the old artist always has endeavored to show as much as possible. In pl. IV the chest of the god who advances to the right is completely turned about so that it appears in a front view. Both shoulders, besides being too much drawn up, are not shortened. The artist evidently desired to bring the emblems of the god into clear view, but was not equal to the task of combining it with a natural attitude of the body; and he probably also hesitated about hiding the face by the arm and hammer. The existence of such a principle among artists of western Asia is evidenced by numerous Assyrian reliefs, upon which the bow and bowstring are simply omitted when they would cover the face or chest. The unnatural position of the arm of the god or goddess (pl. I) is probably to be explained in the same way. In order that the vessel might not obscure the drapery, evidently executed with much care, the artist extended the arm far to the front. Upon a relief at Ueynek, which depicts a person ascending a ladder, the ladder is represented with a front view, but the person with a side view, so that he seems to climb upon the cross beam of the ladder. On this as on other sculptures the artist tries to do justice to the laws of perspective by shortening the figures in the background, but does not maintain a proportion as regards their breadth or in relation to the other figures. Thus on a relief from Marash a warrior is considerably larger than the horse which he leads by the bridle. Frequently also rear figures are placed on the same level as front ones, giving the appearance of adults and children, although judging from the above characteristic this is not at all intended. Where several rows of figures ranged one behind the other are to be represented, as upon the Marash relief mentioned above, they are placed, as on steps, one above the other, because the

artist could not conceive and reproduce a picture in its entirety, but could only take each group separately in view.

The attitude of the body is conventional. The personages are represented as walking by placing one foot in front of the other. One arm is extended to hold or carry a staff, a vessel, or an ornament and similar objects, the other is bent at a right angle and placed against the chest. There seems to be no attempt at individualizing. Even where several personages or animals appear, each figure, almost without exception, is moving in the same attitude as the other. The eye is always drawn with a front view and is generally too large. Profile representation is the rule. The only example of drawing with front view is upon a relief found at Carchemish representing a winged goddess, which is certainly due to Babylonian influence, as the goddess Ishtar very often appears in that attitude on seal cylinders of that country. The lifeless monotony of Hittite art is enhanced where only a single personage is represented, which is mostly the case. The cooperation of several personages on the same tasks is seldom observed, even where a larger sculpture series is found. For even here each figure generally seems to be so little influenced by the action of its neighbors that its absence would not be missed. Battle scenes are until now entirely wanting. On the other hand we have the representation of a lion hunt, accompanied by a Hittite inscription, which belongs to the better productions of this art. Upon a war chariot, supposed to be drawn by two horses, although only one is sketched, while the other must be imagined as covered by it, there stands by the side of the charioteer a bowman in the act of shooting an arrow at a fleeing lion. The lion, already hit by an arrow and infuriated by it, rears high upon his hind legs and with terrific roaring turns the upper body, with raised fore claws, toward the bowman. Under the horse a dog is represented in a rapid run. A very similar representation of a deer chase, evidently coming from the same place, has recently been discovered.

As regards technology the Hittites seem to have been quite skillful in working metals. The mountains between Cilicia and Cappadocia are rich in silver, and silver mines were found which must have been worked in very ancient times. And, indeed, among the few remnants of Hittite industry that have come to us there are several objects of silver such as the sword knob in figure 2 and some seals. In one of them, artistically executed, the several parts are held together with silver alloy. The Hittite treaty, described on a previous page, was engraved upon a silver tablet. Bronze works have been discovered in the excavations on the soil of the Kingdom of Van. One of these is a bronze votive shield, upon which rows of walking lions and bulls in repoussé are represented in concentric circles around the center of

the shield. Besides there were found arm rings, belt buckles, parts of artistic thrones and statues of bronze. The statues and animal figures had been covered with very thin gold plate and set with gems, the gold plates being fastened to the bronzes by narrow bent edges sunk into cuts in the bronze.

The excavations in Van brought to light a unique floor mosaic composed of black, white, and red stones combined with bronze. Around a bronze rosette the colored stones are grouped in concentric rings. Other figures of the same material are worked into rhombic forms.

CENTRAL AMERICAN HIEROGLYPHIC WRITING.

By Cyrus Thomas.

The Mayan tribes of Yucatan, Chiapas, Guatemala, and western Honduras had reached at the time of the "discovery" the highest stage of native culture found in North America, except possibly in political organization, in which the ancient Mexicans, or Aztecs, excelled. This advance is shown by their architecture, as seen in the ruins of stately stone structures found throughout the region indicated, by their sculptures in stone and wood, by their complicated calendar system, by their arithmetical computations, and, above all, by the near approach they seem to have made to alphabetic writing, their system falling apparently but a step behind that of the ancient Egyptians. They engraved their peculiar hieroglyphic characters on stone tablets, on great sculptured monoliths, and on the walls and lintels of their buildings, painted them on plastered surfaces and on pottery, and wrote them in books. As most of these glyphs have rounded outlines, early authors imagined they resembled somewhat a section of a pebble, and the term "calculiform characters"—from the Latin calculus, "a pebble"—was for a time applied to them; but this is no longer in use, the term "hieroglyph," or simply "glyph," having replaced it. Where inscribed on stone or wood (for they are carved on both, but chiefly on the former) they are made to stand out in low relief, as may be seen in plate 1; but occasionally they were scratched or incised on shells and pottery, in which cases the glyphs are generally quite rude.

Inscriptions composed of these peculiar hieroglyphs have been found in the ruins of temples and of other structures in the States of Chiapas and Yucatan, Mexico, and in Guatemala and western Honduras. They are found in different situations, some of them on stone slabs set in the inner side of the walls of the temples, one of which, from Palenque, Chiapas, is among the collections of the Smithsonian Institution. A very extensive inscription is on the inside wall of the structure at Palenque, named by Stephens the "Temple of Inscriptions." At Copan, in western Honduras, and at Quirigua, in eastern Guatemala, the more important ones are on the sides and backs of the great stone statues which stood, and, in part, are yet standing, in what the native priests considered sacred precincts. The

lintels of the temple doors and, in a few instances, even the steps leading up to these edifices were utilized for this purpose. Casts and excellent photographs of most of these inscriptions have been made, thus bringing them in reach of students for investigation and study. Most of the ruins are found covered with a heavy forest growth, which has to be removed before exploration can be carried on. The present condition of one of the ruins at Chichen Itza, in Yucatan, named by Prof. W. H. Holmes the "Temple of Tables," is shown in plate II, where the growth has been partially removed.

The glyphs of the inscriptions, which were carved so as to stand out in low relief, are, as seen in plate I, somewhat square in outline, varying from 3½ to 4½ or 5 inches square. Each of these squares, which are as a rule in straight columns or lines, constitutes a hieroglyph or glyph, but they are usually composed of several elements or parts. This characteristic, which can not be easily explained in words, will be readily understood by reference to plate I. Some of these elements, as will be observed, consist of lines and dots, mostly at the left side or on the top of the glyphs. These are of special importance and will receive further notice. Some of the glyphs consist chiefly of an oval figure surrounded by a rim, as in the Egyptian cartouch. These inclosed characters, with probably a single exception, are symbols of Maya days. It is by means of these day symbols and the month symbols, which are also given in the inscriptions, that students ascertain that Maya people were the authors. Diego de Landa, a Spanish bishop, who went to Yucatan as a missionary in 1540, when persons were still living who could read the symbolic writing of the codices, has preserved in his work (De las Cosas de Yucatan) the forms of these symbols, each with its proper name attached, and this is the initial point of later investigations. As these names are those of the Mayan days and months, and the ruins are in the regions inhabited, so far as known, only by Mayan tribes, the remains as well as the inscriptions are attributed to these tribes.

However, Maya scribes were not limited in their symbolic or hieroglyphic writing to stone or wood, but wrote or painted their characters in manuscripts. Four examples of these manuscripts, or codices, as they are usually termed, remain. These are the Codex Troanus and Codex Cortesianus, thought by some authors to be parts of the same book, which are at Madrid; the Codex Peresianus, which is in Paris, and the Codex Dresdensis, the most important of the series, which is in the Royal Library at Dresden.

The first two strongly resemble each other, and were probably written in Yucatan, as they follow the calendar system of that region. The Codex Peresianus differs in some respects from all the others. The Dresden codex, which is of chief importance in studying the

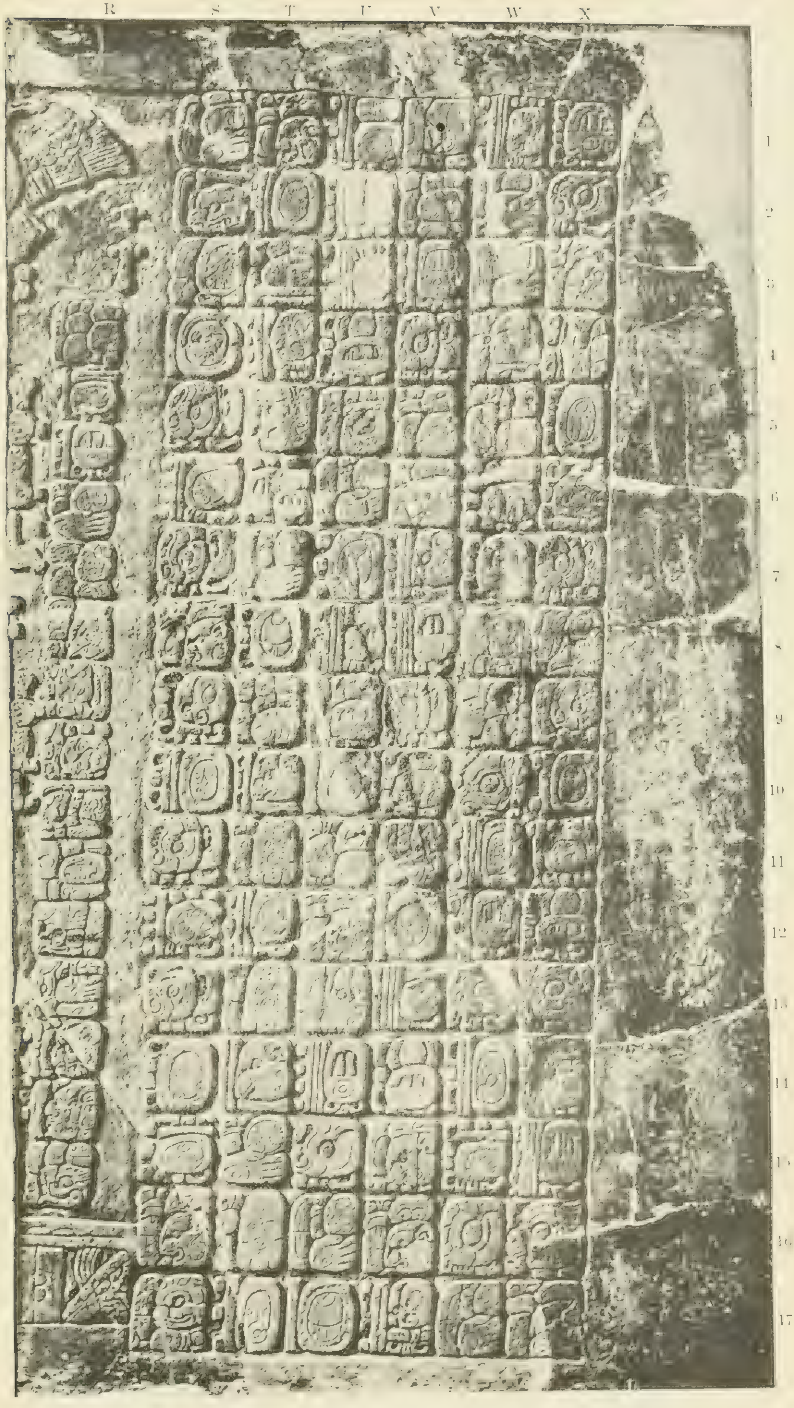

FIG. 1.—PALENQUE TABLET (IN SMITHSONIAN INSTITUTION).

FIG. 2.—TEMPLE OF TABLES, CHICHEN ITZA.

written glyphs, agrees closely with the temple inscription in essential points, and was probably written in Chiapas or Guatemala.

These manuscripts are on a kind of paper made of the Maguey plant. A description of one is substantially a description of all, though the size and the number of pages vary. The Troano codex, which will be taken as an example, consists of a strip of maguey paper about 14 feet long and 9 inches wide, both surfaces of which were first covered with a white paint or varnish. The two faces were then divided into spaces about six inches wide by black or red lines across the strip, in which spaces the characters and figures, in black, brown, red, and sometimes blue, were painted. The strip was then folded back and forth, like a pocket map, into 35 folds corresponding with the cross lines, representing, when pressed together, the appearance of an ordinary octavo volume. The glyphs and figures cover both sides of the paper, forming 70 pages, the writing and painting having been done apparently after the folding, as the folds do not interfere with it. A page is shown in facsimile in plate III.

The order in which this writing—if it may properly be so termed—is to be read was for many years a subject of discussion, some authors contending for one direction, as from left to right, or from the top downward, while some thought that the reading should be in the opposite direction. The proper order in which the inscriptions and the text, in part, of the manuscripts is to be read was first pointed out by the writer in 1882.[a]

In the inscriptions, which usually consists of two, four, or six columns, the columns are to be taken by twos or pairs from left to right, and the glyphs in each pair of columns are to be read from left to right and from top to bottom, in the order of the letters in the diagram (fig. 1). Where there is a single column the reading is from the top downward, and in single horizontal lines it is from left to right. The order in which the glyphs in the codices are to be taken, where there is a regular arrangement, is substantially the same. Although the columns may consist of but two lines in depth they are read in the order *a*, *b*, *c*, *d* in the diagram, at least in the Dresden, Troano, and Cortesian codices. In the Dresden codex, however, the numeral and time series, some of which are quite long, are in some cases to be read from right to left by lines across the page, the lines following one another from the bottom upward. Usually there are in the inscriptions, besides the glyphs, figures of priests and deities, and symbolic representations. A considerable portion of almost every page in the codices consists of

a	*b*
c	*d*
e	*f*
g	*h*

Fig. 1.

[a] Study of the Manuscript Troano.

pictographic representations such as are seen in the spaces below the text or lines of glyphs in plate III.

An important class of characters consists of those which as is now known denote numbers. These are of two quite distinct types; one, which is the usual form, found in both the inscriptions and the codices, but more abundantly in the latter, consists chiefly of dots and short lines. Thus . (one dot) signifies 1; .. (two dots) signify 2, and so on up to 4; 5 is indicated by a single short straight line, thus —; 10 by two similar lines, and 15 by three similar lines. To represent 6 the Maya scribes used a straight line and one dot ·; for 7 a straight line and two dots, and so on to 9. Eleven was denoted by two straight lines and a dot; 12 by two straight lines and two dots, and so on to 19, which was represented thus ⁘≡. The lines and rows of dots are usually horizontal in the codices, the dots above as shown here, but in the inscriptions, where they are always attached to glyphs, are mostly perpendicular and placed at the left side, as at T 17 and U 17, plate I (the columns in the figure being denoted by letters at the top and the horizontal lines by figures at the side as in a reference map).

FIG. 2.—Symbols for number 20.

The numeral symbols of this type do not appear to have been used for a greater number than 19, other characters and relative position also, as will be shown, being used for higher numbers. Line and dot numerals of two colors are quite common in the codices, the one class black, the other red; but the red characters are not used (except in a single unexplained instance) to denote a number greater than 13, and refer almost exclusively to the numbers given to the days, as explained on a subsequent page. This is one instance, at least, in which color

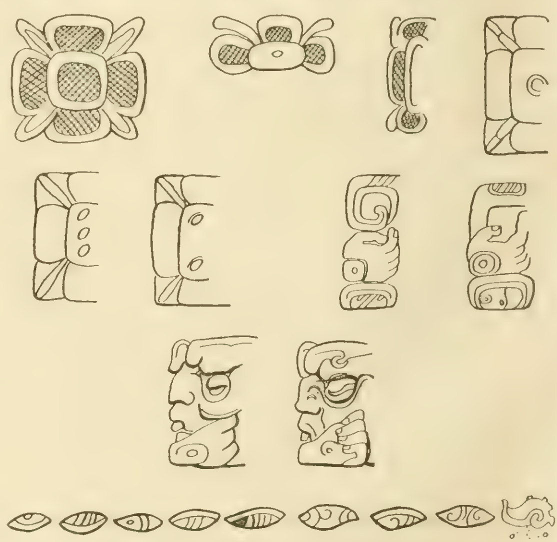

FIG. 3.—Symbols for 0, or full count.

Copy of Plate XXIX, Codex Troano
(Brasseur de Bourbourg's Edition)

has special significance in these native manuscripts and suggests the probability that the different colors of the dots used to denote numbers in the Aztec codices in the time counts have a specific meaning, though this has not as yet been determined.

The number 20 is represented by several different forms, as shown in fig. 2. Those marked *a*, *b*, *c*, *d*, and *e* are found only in the codices; those marked *f*, *g*, *h*, and *i* occur chiefly in the inscriptions and are attached to the left side of the glyphs. Naught (0) is also represented in the inscriptions by characters numbered 1 to 10 in fig. 3, those numbered 1 to 8 being placed at the left side or on top of the glyph when used. Numbers 9 and 10 of the figure are used chiefly in double-face characters, as those seen in fig. 6. Number 11 of fig. 3 shows the characters for naught (0) used in the Dresden codex. The use of these symbols for naught is interesting, as it manifests a very strict adherence to mathematical steps in the representation of numbers, no blanks being allowed.

The Maya scribes were capable of carrying their numeration to a high number, and this they did in the codices, not with new or different symbols from those mentioned, but by relative position, on the same principle that we denote higher numbers than the Arabic digits by the position of these digits. Thus we increase the value of a number tenfold in our decimal system at each step to the left, while in the vigesimal system, used by the Maya scribes, the numbers increased twentyfold at each step. to indicate which they placed their digits, if we may so call them, in a column increasing from the bottom upward, so that a line and dot, mentioned above as denoting 6 if placed at the bottom, as seen in the margin of the page, would denote 6, but if placed one step upward would denote 120, or 6 by 20, and one step higher would, according to their regular vigesimal system, be equal to 2,400, or 6 by 20 by 20, but in their time counts, which are the only numeral series in the third place, or third order of units, would be 6 by 20 by 18, making 2,160. The other steps upward increase uniformly twentyfold. As they rise as high as the sixth step the value of the unit in the several steps or orders of units would be as shown in the column at the margin. As the day was the primary unit, a single dot in the sixth step or order would denote 2,880,000 days. A single dot in the fifth order would denote 144,000 days, and two dots in that place would denote twice that amount; three dots, three times that amount, and so on up to 19. This applies to each of these orders, except that in the second, where 18 is the multiplier. The highest number that can be inserted is 17. They are the same in principle as our compound denominate numbers—as pounds, shillings,

•	equal	2,160
•	equal	120
•	equal	6

6th order	2,880,000
5th order	144,000
4th order	7,200
3d order	360
2d order	20
1st order	1

and pence—the highest number given in the pence place is 11, as 12 would be 1 shilling; and 19 the highest number to be given in the shilling place, as 20 would be £1. These series, or units of the various orders, can be reduced to the lowest denomination which is days—in the same way that pounds, shillings, and pence are reduced to pence. Some of the numeral series in the Dresden codex amount when reduced to over 12,000,000 days.

As an example of their use of large numbers, one numeral series from plate LXIX of the Dresden codex is presented here, the numbers indicated by the numeral characters being placed at the left in parentheses and the equivalents in days at the right. The names placed at the extreme left (great cycle, cycle, etc.) are those adopted by Mr. Goodman for the respective orders:

			Days.
(great cycles)	(4)	equal	11, 520, 000
(cycles)	(5) ______	equal	720, 000
(katuns)	(19)	equal	136, 800
(ahaus)	(13) . . .	equal	4, 680
(chuens)	(12) . .	equal	240
(days)	(8) . . .	equal	8
Total...................			12, 381, 728

That is to say, 4 great cycles (or 4 units of the sixth order or position) equal 11,520,000 days; 5 cycles (or 5 units of the fifth order) equal 720,000 days; 19 katuns (or 19 units of the fourth order) equal 136,000 days; 13 ahaus (or units of the third order) equal 4,680 days, and so on.

The total amount expressed by this series is over 12,000,000 days. This is a large number to be handled by a pre-Columbian native, yet it can be demonstrated by actual count that the Maya scribe used this number correctly in a calculation.

Writers of the present day have adopted the simple method of expressing these numeral series thus (using the above example), position indicating the orders of units 4–5–19–13–12–8, ascending toward the left just as we may express £4, 12 shillings, and 6 pence, thus — 4-12–6.

A knowledge of the Maya numeral system and method of counting and expressing numbers, as given above, is absolutely necessary in the attempt to decipher the glyphs. It is also necessary to give here a brief notice of the Maya calendar, as a knowledge thereof is another requisite in deciphering. The process with the Maya glyphs, so far as it has been carried, is wholly different from the method pursued in deciphering Egyptian hieroglyphs and the cuneiform inscriptions of Assyria. There the phonetic value of the characters being ascertained, the combinations to form words can be followed and tested by the

result. In the Maya, with the few exceptions which will be mentioned later, the glyphs, so far as determined, are to a large extent symbols (not phonetic characters), used to denote numbers, days, months, etc. Hence the only means so far discovered by which to test an interpretation is the demonstrable relation of one character to another, thus: Having a symbol known to be that of Monday, another to be that for 7, another to be that for the month of March, and another for the number 120, and finding them placed in an inscription in the order: Monday, March 7, 120, and this followed by two imperfect or unknown characters and 5, thus ——?——? 5, and having ascertained that the intermediate numbers, as the 120 in this case, indicate the number of

Fig. 4.—The symbols of the months.

days from the first date to a second, we count 120 days from Monday, March 7, which brings us to Tuesday, July 5. This gives us Tuesday and July as the two unknown or doubtful characters of the terminal date. Just as it is necessary, in the example given, to understand, in part at least, our Gregorian calendar, so is it necessary to understand the Maya calendar in attempting to decipher the Maya hieroglyphs.

The Maya years consisted uniformly of 365 days, no reference to or evidence of bissextile years (corresponding to our leap year) having been found in the codices or inscriptions. They were divided uniformly into 18 months of 20 days each, and a supplemental month of 5 days following the 18th. Each of these months had a name and a

symbol as shown in fig. 4. They always followed one another in the same order, the year uniformly beginning with Pop. The 20 days were also named, each having its appropriate symbol as shown in fig. 5. The order in which they followed one another was uniform, though the year did not always begin with the same day, the 5 in the supplemental month carrying the count forward 5 days each year. Although the days had their month numbers, as 1, 2, etc., to 20, as we say the

FIG. 5.—The symbols of the days.

fifth, sixth, and seventh day of the month, there was another numbering which applied to the days only. This, however, was from 1 to 13, beginning again with the unit. These numbers were prefixed to the days and followed in regular succession, no day being without its number. It follows from this method that a day bearing both the same name and the same number will not recur until 13 months have passed. This gives a cycle or period of 260 days, which appears to have been

more in use as a ceremonial or religious period, both among the Mayas and Mexicans, than the secular year of 365 days.

The order of the days and their numbering passed on from month to month and from year to year without a break or change in the regular succession. There is one series of 312 years in length in the Dresden codex, in which there is not a break in the succession, nor an indication of a bisextile year. In the series given above, also from the Dresden codex, which covers 34,059 years, 9 months, and 13 days, the date of the commencement and of the ending being given, which calculation shows to be correct, this is evidence that there can be no break or change in the succession of days, day numbers, or months. In this regularity of succession lies the possibility of determining the time series of the inscriptions and the codices.

In order to show what advance has been made in deciphering this ancient American writing, it is necessary to present examples from the codices and inscriptions that the reader may have the glyphs referred to before him, for words alone can not describe them so as to be understood. Beginning with the inscriptions, which appear to be older than the codices, attention is called to plate I, showing the inscription on the Palenque tablet in the Smithsonian Institution. As a means of identifying the individual glyphs, a letter is placed over each column and a number at the side opposite each line, as in reference maps. R, S, T, U, V, W, X have been selected because they are the letters used for these particular columns in Doctor Rau's scheme.[a]

The column R being separated from the others, and a single column, it must be read from the top downward. Passing by this, attention is called to the other six, which are to be read two and two, beginning with the two at the left, going from the top downward, taking the glyphs alternately in the left of the two columns and then in the right, thus: First glyph, S 1 then T 1; next, S 2, T 2; then S 3 and T 3, and so on to the bottom. Then columns U and V are to be taken in the same order, and after these columns W and X. As it would require a somewhat extended study of the subject to follow out understandingly a complete explanation of the steps in the process of decipherment, an outline only of what has been accomplished in this direction can be given.

Reading down columns S and T in this manner, the first glyph which has been determined, or rather could be determined if uninjured, is T 2 (or the second in the T column), which, from the surrounding border or band and the number attached is known to be the symbol of a day, but on account of the imperfect markings or weathering of the face, is not indentifiable with certainty. Here, however, is an instance where a knowledge of the Maya calendar system

[a] Palenque Tablet, in Sm. Cont. Knowl., vol. XXII, p. 61.

becomes important, as it enables us to limit the investigation to one of four out of twenty days. As the next glyph which follows—that is, S 3 (or the third in the S column)—is the symbol for the month Pop (see fig. 4), the first month of the Maya year, and has attached to the left the symbol for 20 (similar to that shown at *i* fig. 2), it is evident that the day at T 2 is the 20th day of the month. As there are but four days (Ik, Manik, Eb, Caban—see fig. 4) in the calendar system used in the inscriptions that can fall on the 20th, it is evident that it must be one of these. The reader will observe by inspecting this glyph in the figure that there are two short perpendicular lines and a dot at the left; these denote that it is the day 11—?

Passing on to S 10, T 10, we find another date, the glyph S 10, being the symbol for the day 11 Lamat, and glyph T 10, the symbol for the month Xul with the numeral character for 6 at the left. For the days mentioned reference can be made to fig. 5 and for the months to fig. 4. However, for the illustration the names of the days and the months are not essential, but are added here to avoid using blanks. It will be observed that above and below the little dot in the numeral characters at the side of each of these glyphs is a little semicircle or crescent. These, which might be mistaken for number dots, have no significance, but are used to fill out the space or to guard the dot.

To be able to say that certain glyphs denote days, others months, and others numbers is one step in the process of decipherment, but the step is a comparatively short one unless their relation to one another and the object of their introduction into the inscription can be ascertained. This relation has been determined in part through intermediate number series. For example, by passing on to glyphs S 12 and T 12, we find the number series 9 days, 3 chuens (or units of the second order), and 13 ahaus (or units of the third order)—or 13-3-9—which, reduced to the lowest denomination, gives 4,749 days. Counting this number of days, according to the Mayan calendar, from 13 Lamat, 6 Xul, the date given in S 10, T 10, and mentioned above, we reach the date 2 Caban, 10 Xul, which is the date given two lines below at S 14 and T 14. That is to say, the number in the numeral series is the exact time included between the immediately preceding and the immediately following date. This is proof positive that there is a connection between the date at S 10 and T 10 and that at S 14, T 14. Nor does the connection series end here. Glyph S 15 is a short-number series of 123 days which connects the date 2 Caban, 10 Xul, of glyphs S 14, T 14, with the date 1 Ahau, 3 Zip of glyphs T 17 and U 1; or, omitting names, it connects the last preceding with the next following date.

Dropping from consideration the names of the days and months, introduced to avoid blanks or explanatory phrases, the important fact

remains that there is a connection between date glyphs that stand some distance apart.

It has been stated above that the Maya writing included two types of numeral characters. One of these, consisting of dots and short lines and the use of position, has been explained. The other type consisted of face characters, some of which are shown in fig. 6. In order

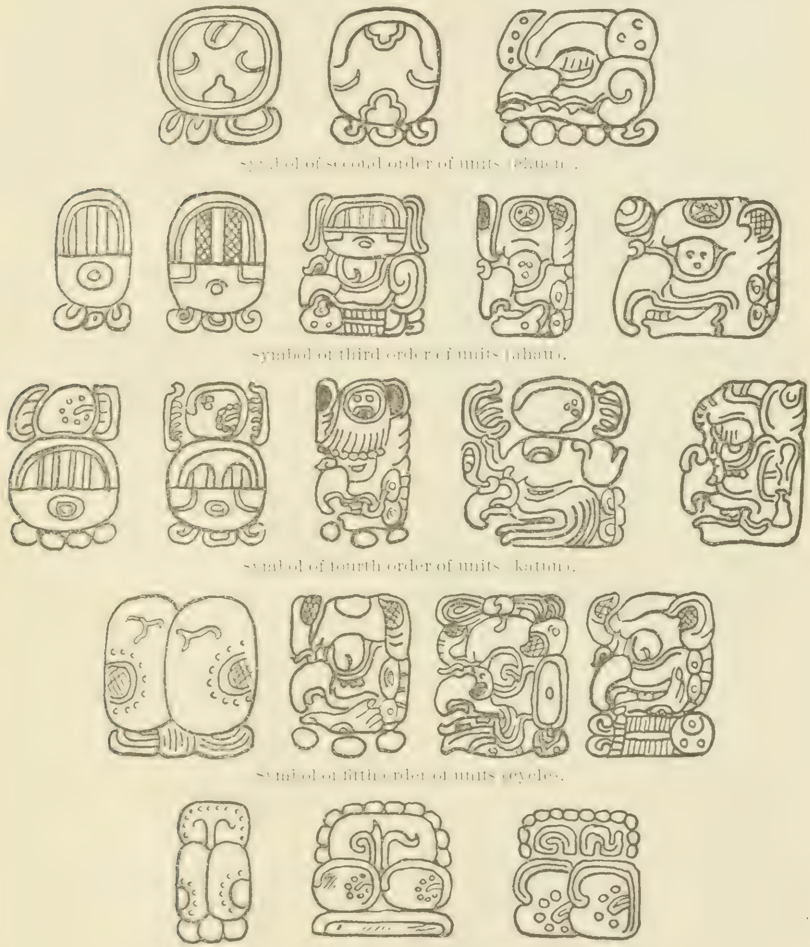

Fig. 6.—Face characters representing numbers.

to show how these are used, attention is called to fig. 7, which represents part of the inscription on the east side of Stela (or statue) F, at Quirigua, Guatemala, as designated by Mr. Maudslay, from whose great work (Biologia Centrali-Americana, "Archæology"), part XII, pl. 40, our figure is taken.

As seen in this illustration (fig. 7), there is at the top or beginning a large quadruple glyph, below which follow, in the order of the numbers 1, 2, 3, 4, 5, and 6 at the sides, six double glyphs, each composed of two faces. There are other double-face glyphs below, but the six will suffice for illustration. Omitting from present consideration the large character at the top, attention is directed to these six glyphs, from which we may learn something of the mistakes made in the attempts at decipherment. A little more than a decade ago there was almost universal agreement among students of the Maya hieroglyphs that these face characters, especially those in commencing series, as shown in fig. 7, were symbols of deities. Subsequent investigation, however, has shorn them of their sacred character and reduced them to mere symbols representing numbers. The left face of each of these six double glyphs is one of the smaller numbers (1 to 19), which we have designated "Mayan digits;" for instance, the left face in glyph number 1 denotes 9; that in glyph 2 stands for 16; that in 3 for 10; that in 4 for 0 (naught), and that in 5 also stands for 0 (naught). These are the numbers prefixed respectively to the symbols of the orders of units in the inscription represented. The right face of number 1 denotes the cycle or fifth order of units; adding the prefix 9, the double glyph will signify 9 cycles or 9 units of the fifth order. The right face of glyph 2 is the katun or fourth order of units; that of 3 the ahau or third order of units, etc. Glyph 6 is the day (1 Ahau) and glyph 12 the month (3 Zip), forming together the terminal date of the series.

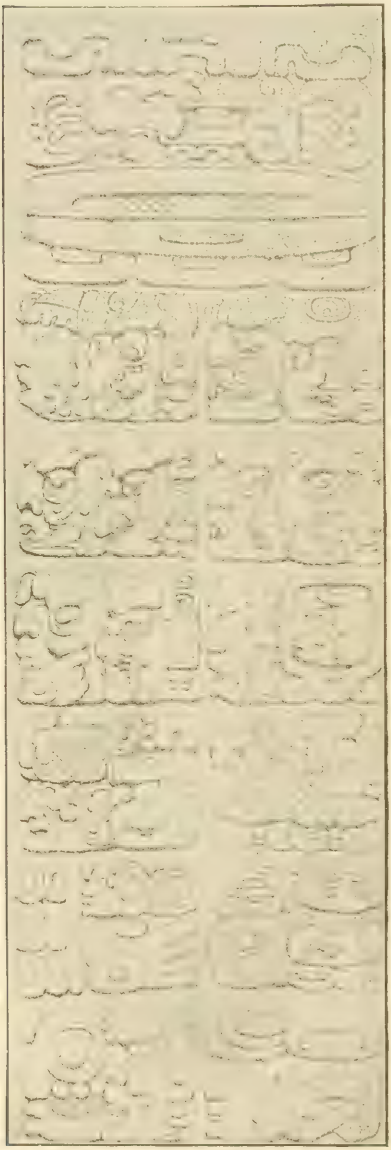

Fig. 7.—Inscription on Stela F, Quirigua. Copy from Maudslay's plate.

Briefly stated, this series (fig. 7) and all those of like character are made up of numbers and dates, and not of deities, as was formerly supposed.

The differences in these face characters, by which their respective values are determined, have not in every instance been so clearly ascertained that they can be determined by inspection alone. In the left face of glyph 1 the circle of dots on the cheek forms the distinguishing characteristic for 9, but peculiar markings of others are less distinct. The face characters representing the orders of units, as the cycle, katun, etc., can be determined by position alone.

The great quadruple glyph at the top is the symbol for the sixth order of units (Goodman's "great cycle"), which seems to have represented the limit of Mayan time counts, although according to Doctor Brinton their numeration in the regular Maya number system was carried a step higher; and Goodman intimates that their time counts reached an additional step in the scale, amounting at the extreme to 280,800 years or 102,492,000 days. This large so-called "great cycle symbol," with the number characters and the immediately following date, form what Maudslay has termed an "initial series," as the large glyph is never found except at the commencement of an inscription.

The month symbol which helps to make up the date in this instance is somewhat distant from the day symbol, five compound glyphs intervening; nevertheless there is numerical evidence that the two are connected and that the date is part of the "initial series." There is also evidence that the initial series in the inscriptions at Copan, Quirigua, and some other localities where the number of cycles is 9, as in this case, start with the same date (4 Ahau 8 Cumhu), this date being apparently the beginning of an era with the priests and scribes of those sections. As this is but one instance of a number where the count in these initial series gives the proper terminal date in the inscription, the proof that they have been correctly interpreted seems to be complete. This conclusion necessarily carries with it the acceptance of the interpretation given the glyphs and also the calendar system as above explained, though the native priests appear to have purposely used characters which would be understood only by their own class.

The codices, as will be seen by referring to plate III, which is a facsimile of three of the four divisions of plate XXIX of the Codex Troano, contain a much larger proportion of pictographic representation than the inscriptions. Besides the pictures there are two classes of hieroglyphs; first, the ordinary numerals represented by dots and short lines, which are of two colors, black and red. The latter, which do not exceed 13 in value, are the numbers attached to or belonging to the days—the day, where the symbol is omitted, as in the lines of the alternate black and red numerals in this instance, being understood.

The column at the left side of the lowest division consists of the symbols of 5 days, which form the basis from which the count by the black and red numerals is made. The day columns for the two upper divisions are in a preceding plate, the line of numerals running through more than one plate.

The two lines of black glyphs running across the upper part of each division forms what may be termed the "text." These are read in this instance by groups of four, considering them two short columns, as those over the bird and personage in blue at the left side of the middle division, the order being the same as *a*, *b*, *c*, *d* in the diagram, fig. 1. But little progress has as yet been made in deciphering this so-called "text."

So far as the writer is aware, but three characters of the text of this plate have been determined save in the manner mentioned below. These are the symbols of three of the cardinal points, and are the first, third, and fifth glyphs in the upper line of the upper division, counting across from the left.

That the text in most instances contains reference to the figures below is quite evident. This is shown in plate III by the fact that some feature of the pictures is represented by one of the four glyphs which stand above it, as in the middle section the bird's head forms one of the glyphs over the figure in which the bird appears; and likewise the dog-like animal and worm in the same division are represented in the glyphs of the text above. These would therefore seem to be simple abbreviated pictographs or conventionalized figures and not in any sense phonetic characters. In the lower division of the same figure the three persons to the right are holding in their hands something like the symbol for the day Ik (fig. 5) (which signifies "wind" in the Maya language): the same symbol appears in the text above the head of each, but its signification in these places is unknown. We may surmise if we like, but the proof is wanting.

As the glyphs in the middle division of the figure, on which the persons and other forms are sitting, appear to represent something out of which plants can grow and has the elements of the symbol of the day Caban (see fig. 5), it is possible they denote earth (cab in Maya signifies "earth"). In the upper division the Kan-like symbols (one of which a bird is pecking and another is bitten by a little quadruped) probably represent grains of corn, supposed to be in the ground, the two to the right throwing out sprouts. If this interpretation be correct, this entire plate probably has reference to the cultivation of corn and the dangers it is subject to. However, from what has been stated, the reader can judge as to the portion of this codex that has been determined with certainty, which is but little, and as to what is as yet but theoretical. Of the text proper, scarcely anything, as before stated, has been absolutely determined. This failure to decipher is attribu-

table in part to the fact that where the suggested signification may be absolutely correct, no means, except where numbers come into play, has been found to verify the conclusion.

From what has been stated and the examples presented from the inscriptions and codices, it is apparent, notwithstanding the number of glyphs whose signification has been ascertained, that practically no progress has been made in determining the phonetic equivalents of these characters. In other words, no satisfactory evidence has yet been presented to show that any of these glyphs are phonetic, although there is sufficient evidence that the language used was Maya. The nearest approach to proof on this point is in regard to a few symbols, such as that for the month Tzotz (fig. 4). The usual form of the glyph is the conventionalized head of the leaf-nosed bat, and in one instance (Stela D, Copan) the full form showing the wings and body is introduced as the symbol of the month. As tzotz is the Maya word for bat, it is possible the word relates to the symbol. Pop, the name of another month, signifies in Maya literally a mat, or rug, the reference being apparently to the structure, and the chief feature of the symbol for the month consists usually of interlacing like basket work. These and a few other instances of similar character constitute the strongest indications of phoneticism that have been observed, but as the elements of these glyphs found where the character can not be determined by other means furnish no aid in decipering them the inference of phoneticism is doubtful. It is possible that some of the characters are phonetic, yet it must be admitted that no satisfactory proof thereof has yet been presented, although the author, with others, thought but a few years ago that continued investigation would soon produce this evidence.

The general purport of the inscriptions has not been ascertained with certainty, yet the fact that half of them belong to the classes heretofore described—the numeral symbols, calendar symbols, etc.—leads to the conclusion that they contain little, if anything, relating to the history of the tribes by whom they were made.

The indications that the Maya priests, by whom these inscriptions were doubtless designed, if not carved, recognized a prime or ruling era from which a large portion of the initial time series are counted, are so strong that most recent authorities who have devoted attention to the subject have concluded to adopt the theory, at least tentatively. We might hope that further research will prove that this has some relation to Maya history were it not that the beginning was placed about four thousand years prior to the time when the inscriptions were made—a date so remote as to preclude the supposition that it related to any noted event in the history of the tribes.

The progress made in deciphering the text of the codices is less than that made in interpreting the inscriptions, as the number of numeral, time, and other symbols in the former which have been determined is less in proportion to the whole than in the latter. However, this proportion is limited to the text of the codices and does not include the accompanying numeral and day series. Nevertheless, the aid furnished by the figures which are introduced, together with the relation a large portion of the time series bear to the text and figures, often furnish some indication of the general purport of the plates, but all attempts to give the details have thus far failed, from the lack of means of verification. Two or three of the plates of the Dresden codex are devoted entirely to a single numeral series. These can be followed throughout and the obliterated characters in most cases restored; in fact, some of them seem to be little else than the steps of the calculation made by the original scribe. Possibly their relation to adjacent series may yet be ascertained and their signification determined. This has been accomplished in regard to the series running through plates 46–50 of the Dresden codex.[a]

A brief answer to the question, What has the progress thus far made in deciphering this hieroglyphic writing added to our knowledge of the ancient history, life, and attainments of the Maya people? may properly close this brief article.

That it has shown a greater advance in culture along particular lines than was previously known is certainly true. Much has been ascertained from the remains of stone structures and the sculptured designs thereon in regard to the advance of the Mayas along certain lines of art and their ability to form and to carry out comprehensive plans and designs; but the study of the hieroglyphs has brought to light evidence of mental capability and attainments of a higher grade in some respects than has been shown elsewhere. It would be somewhat difficult for anyone at the present day, except a mathematician, to calculate back 34,059 years 9 months and 13 days from a particular day in the present year, using our Gregorian calendar, and determining the exact month, day of the month, and day of the week that will be reached. Yet this was accomplished by the Maya priests according to their calendar and with their cumbersome vigesimal system. Not only was it necessary to reduce the several orders of units (cycles, katuns, etc.) to the lowest denomination, but the sum had to be changed into years, months, and days. The modern mathematician has his books of tables, and his paper, ink, and pen and pencil, and a numeral system that is simple and easy to handle. How did the Mayan scribe solve the same problem with the means he had at hand? The study of the glyphs has brought these facts and this question before us.

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[a] The Maya Year, by Cyrus Thomas, Bureau Am. Ethn., 1894.

The steps which have been made in decipherment have made it evident that the Mayan priests had an understood era or a well-understood point of departure in their time counts. They also indicate that the inscriptions at Copan and Quirigua were carved in substantially the same period, the range, judging by the terminal dates of the initial series, being comprised in two hundred years. But the attempts to connect the dates in the Mayan inscriptions and codices with dates in the Gregorian calendar have failed, though greater success has attended the efforts in this direction with the Aztec count. Another fact made prominent by the study of these glyphs is the uniformity in the system, art, and culture, along the lines indicated, in Chiapas, Guatemala, western Honduras, and with slight exceptions in Yucatan. The collection of hieroglyphs from the inscriptions of the latter section are not sufficient to determine whether they follow the Troano and Cortesian codices or the system of the inscriptions of Chiapas and Guatemala.

The study of the inscriptions and codices has made it evident that no adjustment between the Maya year and the solar year was made in any way that appears in the record or interfered with the calendar count. Although the efforts at interpretation have succeeded in few if any instances in tracing the connection throughout long inscriptions, they have made it evident that there is connection, or, in other words, that these inscriptions (with possible exceptions) are continuous records from the initial glyph to the end, though it may consist of little else than number series and time counts. Both inscriptions and codices evidently relate very largely to ceremonies and priestly duties, more particularly the latter.

Another result of the study of the hieroglyphs is the clear distinction it has established between the Maya and the Aztec symbolic writings.

The Maya writing has been studied to a greater or less extent by Leon de Rosny, Hyacinth de Charencey, and Brasseur de Bourbourg, of France; P. Schellhas, E. Forstemann, and Eduard Seler, of Germany; A. P. Maudslay, of England; Charles Rau, Edward Holden, D. G. Brinton, J. T. Goodman, Marshall H. Saville, Cyrus Thomas, G. B. Gordon, and C. P. Bowditch, in the United States.

TRACES OF ABORIGINAL OPERATIONS IN AN IRON MINE NEAR LESLIE, MO.[a]

By W. H. Holmes.

Early in April, 1903, a communication was received by the Bureau of American Ethnology from Dr. S. W. Cox, of Cuba, Mo., stating that evidences of ancient mining operations had been discovered in an iron mine operated by him near Leslie, Franklin County. This report was confirmed by Mr. D. I. Bushnell and other St. Louis archeologists, and the present writer, who is especially interested in the quarrying and mining industries of the aborigines, repaired at once to Leslie to make a study of the interesting phenomena.

It was found that the miners had encountered a body of iron ore, of unknown depth and horizontal extent, lying immediately beneath the surface of the soil on a gentle slope reaching down to the banks of Big Creek, a branch of Bourbois River, and that they had removed the ore from a space about 100 feet wide, 150 feet long, and to a depth at the deepest part of between 15 and 20 feet, as shown in plate I. In beginning the work traces of ancient excavations were observed penetrating the soil which covered the surface of the ore body to a depth of from 1 to 5 feet, and as the work progressed it was found that the ore had been fairly honeycombed by the ancient people, the passageways extending even below the present floor of the mine, as at the right of the figure in the plate. There were many partially filled galleries, generally narrow and sinuous, but now and then larger openings appeared, two of these being of sufficient dimensions to accommodate standing workmen.

In the débris of the old excavations many rude stone implements were encountered, and upward of 1,000 of these had been gathered by the miners into a heap on the margin of the mine. (Pl. II.) These sledges are exceedingly rude, consisting of hard masses of stone or hematite weighing from 1 to 5 pounds, and roughly grooved or notched for the attachment of withe handles, no trace of the latter remaining, however. The great number of these implements made it certain that extensive operations had been carried on by the ancients.

[a] Reprinted, with additions, from the American Anthropologist, vol. 5, No. 3, July–Sept., 1903.

but the exact nature of the work was not readily determinable. The first impression was that the compact masses of hematite were sought for the purpose of manufacturing implements such as were employed by the mound-building tribes in many parts of the Mississippi Valley, but examination revealed few traces of the shaping of this material, save that it had been used in making the rude sledge heads or hammers found in the mine. In breaking up the ore the white miners encountered small, irregular seams and masses of flint, but these were too limited in extent and too brittle in texture to have been utilized successfully in the manufacture of implements. Some workable flint was observed in the vicinity of the ore body, and flakes and rejectage of blade making, as well as a number of well-finished spearheads, arrow points, and leaf-shaped blades were intermingled in the filling of some of the superficial pits, but this flint shaping appears to have been an incident only of the work on the site. The evidences of this shaping work are not sufficient to warrant the conclusion that the extensive tunneling was carried on for the purpose of obtaining material for that purpose. Besides, this flint is found in large bodies in many sections of the general region and could readily have been obtained in quantity by the Indians.

It was observed, in approaching the mine, that the exposed surfaces of the ore and the ground about were everywhere a brilliant red. The workmen were red from head to foot, and anyone venturing to handle the ore soon found his hands smeared with red oxide, repeated washing being required to remove it. The prevalence of the red color suggested at once the idea that the site had been an aboriginal paint mine and that the red and yellow oxides were mined and carried away to be used as paint—an article of utmost importance in the aboriginal economy.

As the charges of dynamite used by the miners broke down the walls of the mine it was observed that the deposits were of irregular hardness, that certain portions of the ore were very compact and flinty, containing much quartz, and of dark-bluish or purplish hue, while the larger part was so highly oxidized as to be easily broken up. Extending through the ore body in all directions were pockets and seams of soft red and yellow oxides, and in places there were irregular openings and partially filled cavities. Two of these openings are shown in plate III, a view of the face of the mine taken by Mr. Clark McAdams, of St. Louis. The miners would drill with great difficulty through the hardest of ore, to have the drill drop suddenly into a cavity of unknown depth. This occurred at the spot shown in plate IV. It was difficult to discover just which of these openings and cavities were artificial, or whether or not they had been penetrated by the ancient workers, as changes are constantly taking place in such ore bodies. Percolating waters fill up or clear out the passageways. Generally,

GENERAL VIEW OF THE IRON MINE, SHOWING THE FACE OF THE ORE BODY AT THE RIGHT WITH OPENINGS OF THE ANCIENT MINES.

Photograph by D. J. Bushnell.

HEAP OF STONE SLEDGE HEADS, ABOUT 1,200 IN NUMBER, COLLECTED ON THE MARGIN OF THE MINE.

Photograph by D. J. Bushnell.

however, as the walls were broken down by our miners the openings were found to connect with the superficial pittings, as indicated in plate V.

It appears certain that the larger tunnels or galleries in which the sledges were found had been opened up or enlarged by the ancient miners and that, in the search for other bodies of the desired product, they had followed weak lines and partially filled passageways, removing the projecting masses of hard ore, where these interfered with the work, by means of the sledges. Sketches of these rude implements are shown in fig. 1, and the specimens appear on plate VI. It is apparent that the sledges could have had no other function than that of crushing and breaking up the solid masses of ore to be used in the manufacture of implements or in opening new passageways through the ore body. Although these sledges were made in the main of com-

FIG. 1.—Sketches of the rudely shaped mining implements.

pact bits of the ore and of the flinty masses associated with it, they correspond very closely in general characteristics with the bowlder sledges used in such great numbers in the copper mines of Lake Superior. Nearly all appear to have been hafted for use, and the majority show the rude grooving or notching necessary for the attachment of the withe haft. It would seem that in the narrow passages of the mine the use of hafted implements would be inconvenient if not entirely impracticable, and we are left to marvel at the feat accomplished by the ancient workmen of penetrating a compact ore body in dark, sinuous passages hardly roomy enough to admit the body of a man, with the aid of rude bits of stone held in the hand. The character of these openings is indicated clearly in plate III, which shows the face of the mine as freshly exposed by the mining operations; and plate V indicates somewhat imperfectly the manner in which the tunnels or borings penetrate the ore body connecting with the superficial

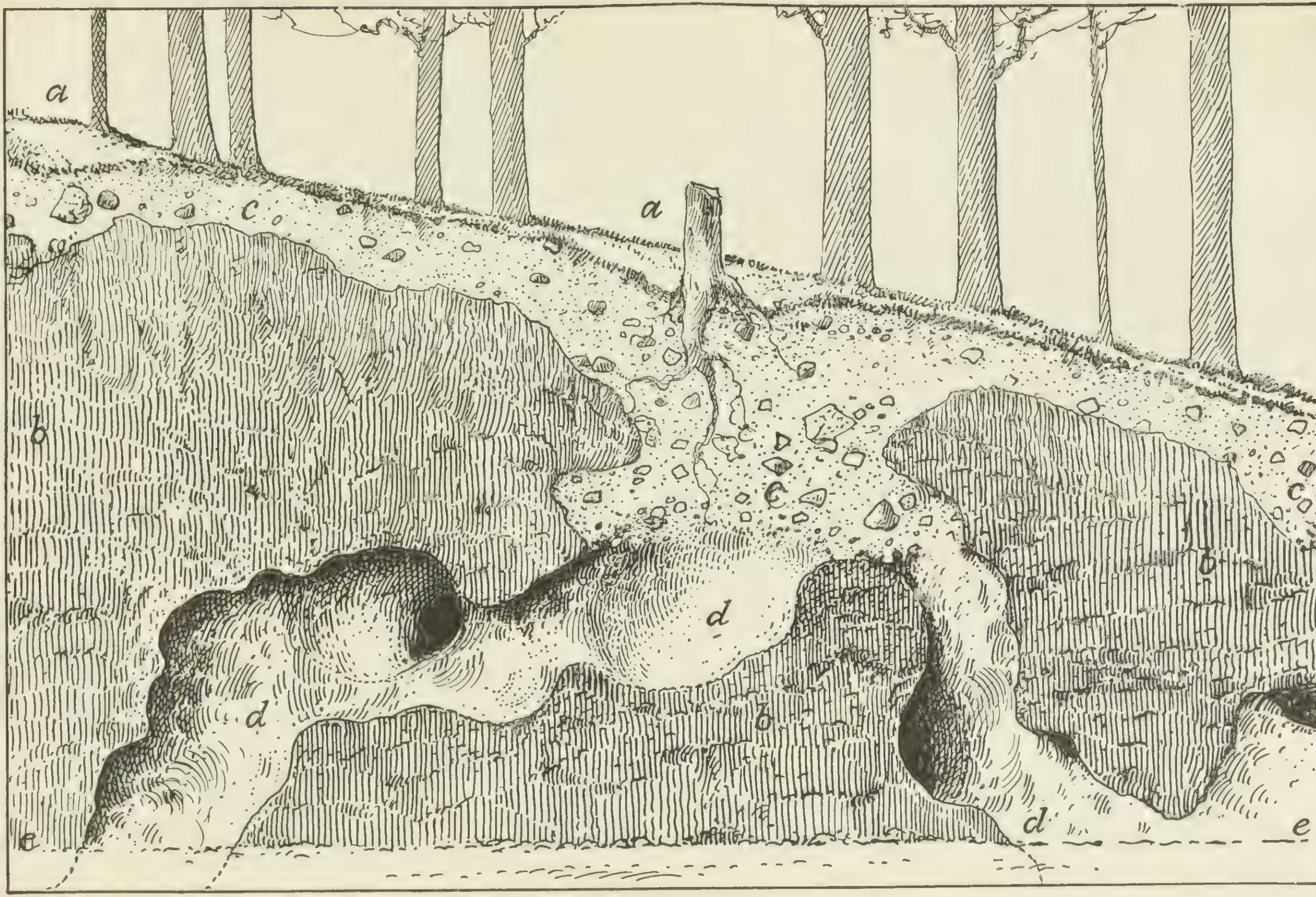
pits and extending to unknown depths beneath the present floor of the mine. Three of these borings are seen in the wall of the mine shown in plate VII. One is exposed at the right of the right-hand figure, and a second occurs beyond this, extending from the stump on the margin of the mine down to and beneath the feet of the man whose back is turned toward the observer, and a third passes down from the second stump, being the same opening as that shown at *d d* in plate V.

Numerous examples of the implements found and specimens of the ore in its various phases, together with a large mass of the compact ore, one surface of which shows the markings of the mining tools of the aborigines, were presented to the U. S. National Museum by the proprietor of the mine, Dr. S. W. Cox.

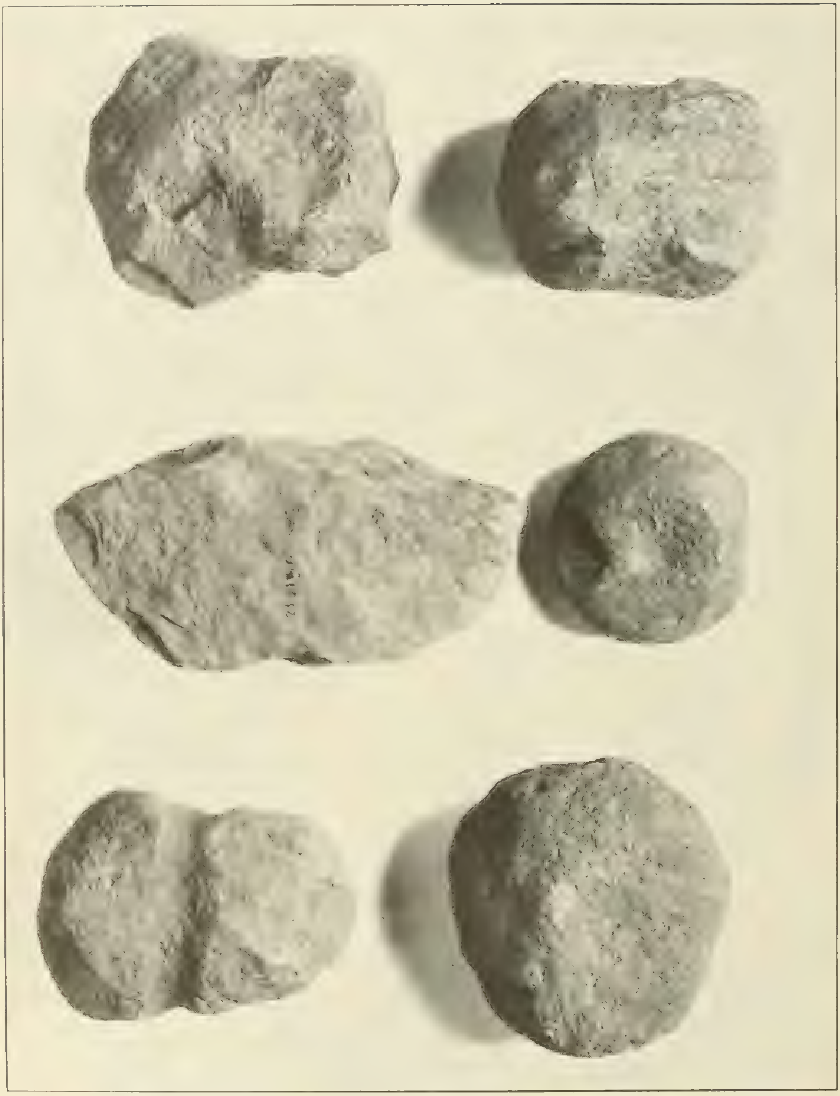
I have now examined mines and quarries of the aborigines in twelve distinct materials, and each new example has added to my former high estimate of the enterprise and perseverance of the native peoples when engaged in the pursuit of their normal industries.

FACE OF THE ORE BODY, SHOWING SECTIONS OF THE ANCIENT MINE OPENINGS.

WORKMEN ON THE OUTER MARGIN OF THE MINE DISCOVER OPEN GALLERIES BENEATH.



SECTION INDICATING THE MANNER IN WHICH THE ANCIENT GALLERIES OR BORINGS PENETRATE THE ORE BODY.



STONE SLEDGE HEADS, HAMMERS, AND RUDE PICK FROM THE ANCIENT GALLERIES.
ONE-THIRD ACTUAL SIZE.

VIEW OF THE MINE WALL, SHOWING TRACES OF THE ANCIENT TUNNELS, EXTENDING DOWN THROUGH THE ORE BODY.

Photograph by Mr. Clark McAdams.

LHASA AND CENTRAL TIBET.[a]

By G. Ts. Tsybikoff.[b]

After a journey of twenty-two days over the sparsely populated north Tibetan plateau, our caravan of pilgrims camped July 19,[c] 1900, on the banks of the San-chu, at the northern foot of the Bumza Mountain. The caravan had been formed at the Kumbum monastery in Amdo, and started April 24 on the way to Lhasa. There were about 70 persons in the party, almost all of them Amdo and Mongolian Lamas, and were quartered in 17 traveling tents. About 200 mules transported men and baggage.

We here first met inhabitants of Central Tibet. Close to the road was a great black tent in which lived the local soldiery, an advance post on the lookout for foreigners. They had special orders to watch during the present year for P. K. Kosloff's Russian expedition, of which the authorities at Lhasa had received information as early as April.

The guards immediately approached our camp, but seeing that it was an ordinary caravan of pilgrims, the men were soon busied in making trifling exchanges to supply their wants, our men keeping a watchful eye on articles that might readily be stolen. After four short marches from here we reached the Nakchu monastery, the residence of two governors of the local nomads, appointed by the central government of Tibet. One of them belongs to the clergy and is called

[a] Translated from the Izvestia of the Imperial Russian Geographical Society, St. Petersburg, vol. xxxix, 1903, part iii, pp. 187–218.

[b] "M. Tsybikoff is a Buriat by birth, and a Lamaist by religion, who finished his education at a Russian university, and, after having prepared himself for this journey, went quite openly, like so many other Buriat pilgrims, to Lhasa. There he remained more than twelve months, making an excursion to Tsetang (or Chetang) and visiting some of the most venerated monasteries, after having previously stayed, during his journey to Lhasa, in the Mongol monasteries of Labrang and Kumbum. During his stay at Lhasa he made, moreover, a most valuable collection of books, written by all the most renowned Lama writers during the last nine centuries. This collection represents 319 volumes on philology, medicine, astronomy and astrology, history, geography, and collections of ku-rims (praises, prayers, and incantations, and so on). It has been presented by the Russian Geographical Society to the Academy of Sciences."—The Geographical Journal, London, January, 1904.

[c] The dates in this paper are old style, or twelve days behind the Gregorian calendar.

"Khambo," the other is a civilian, called "Nansal." They supervise the collection of taxes and decide important matters that arise between the natives; and also control the government stations between Nakchu and Lhasa. It also devolves upon them to stop Europeans bound for Lhasa and immediately to notify the central government about them, as well as about all suspicious persons. I was halted as belonging to the last category, due to the chief of our caravan, who, out of friendship to the Tibetans and possibly to shift responsibility from himself, reported that there were Buriats in the party. Although the Buriats had of late been freely admitted, yet we were each obliged to pay 5 taels (about $4), which at once excluded us from the suspicious class and opened our way to Lhasa.

The Nakchu monastery serves also as a custom-house. Here all pilgrims are obliged to pay a tax on each tent, the revenue being used for keeping the local pastures in grass. No penalty is imposed upon those who refuse to pay the toll, although an indirect punishment is inflicted by prohibiting the local residents from having anything to do with delinquents.

After losing half a day here, the caravan left the monastery, situated on the left bank of the small river Dre-chu,[a] and 7 miles away approached the left bank of the Nakchu. In the rainy season, when the river runs deep and swift, it is impossible to cross without boats, which evidently the native nomads can not build. Thence the caravan reached the broad Sun-shan Valley, bounded on the north by Mount Samtan Kansar. From this valley, across the low crest of Chog-la, the road enters the Dam Valley, inhabited by descendants of Mongols brought into Tibet by the Khoshot Gushi Khan in the middle of the seventeenth century. They are at present practically assimilated with the Tibetans, although some still use Mongol felt tents, and have not forgotten how to milk the mares and to make kumys. Mongol words have disappeared from their language, except official titles and some special technical terms. The Dam Mongols are subject to the Manchu Amban, who resides at Lhasa. Their occupation is cattle raising.

From Dam across Lani-la, or "double range," we enter a pass where we come to the first agricultural settlement of Central Tibet. It is more civilized here. The Pondo-chu is crossed by pedestrians over a bridge. In the rainy season baggage is taken across in skin boats, while animals ford the stream. On the right side of this swift river stands the castle Pondo-dzong.

Twenty-seven miles farther on the journey we reached Penbu, or Penyul, one of the most thickly populated regions of Tibet. Caravans have from here a choice of two roads—one, without crossing the ridge, along the right bank of the U-chu, and the other, straight

[a] Chu = river in Tibetan.

across the high ridge of Go-la. About ten miles from the top of the ridge lies the capital of Tibet, Lhasa, which we entered August 3, 1900, after three month's journey from Kumbum.

Central Tibet—that is, the two provinces of U (Wei) and Tsang—has not been visited by Europeans since 1845, at least the principal part of it, although the literature on Tibet in general has increased every year. No Russian traveler entered the country either before or certainly after the prohibition. But for the last thirty years Tibet has been annually visited by Buriats and Kalmuks, who are Russian subjects. Many of these pilgrims made notes on Tibet, but thus far only the report of Zayaeff (eighteenth century), and the diary of the Kalmuk Baza-bakshi have been published.

It must be borne in mind that having penetrated a forbidden country in the guise of an ordinary pilgrim, obliged to pose before the natives as one in search of salvation in the holy land, and constantly in danger of suspicion as other than a pilgrim, the amount of information gathered under such circumstances could not have been great. I was well aware that several years ago an Indian penetrated Central Tibet and established connections with a certain ecclesiastic in Tashilhunpo, that through this lama's servant he received books at Calcutta, and that both lama and servant were executed at Lhasa for daring to allow the admission of a foreigner.

Tibet is truly a land of mountains, and the natives aptly call it "Snowland." In the region we traversed while in Tibet there are two snow mountains, Samtan-Kansar on the eastern end of the Nyan-chu-tangla and the crest of Kar-la on the southwestern side of the circular lake, Yamdok. The mountains that did not reach the snow line were nearly all treeless and their tops bare.

The upper lands of the river valleys are narrow and unfit for cultivation, but the middle and lower portions are wider and enable the industrious Tibetans to grow cereal crops. The steep and rocky mountains are the source of many swift streams during the rainy season, but most of them dry out when the rains cease. Many streams and springs, however, collect water at each rainfall in numerous irrigating ditches that keep the water mills busy.

The year may be divided into two seasons, rainy and dry. In 1900 the dry season commenced in Lhasa on September 13, when the last rain of the year fell. October and November were entirely dry. The first snow fell December 7, but melted the next day. It snowed once in January, in February three times, in March four times. The first thunder was heard on March 14, and twice in April. The snow melted in the valleys immediately after falling, but remained for a time on the mountains. The first considerable rain fell on May 5, then on May 7, June 8, July 17, August 13, and twice early in September. These rains were generally late in the evening or at night,

in squalls and large drops, and in May and June were frequently accompanied with hail. The clouds generally moved from west to east.

Temperature observations were recorded at dawn, 1 p. m., and 9 p. m. for two hundred and thirty-five days. The average morning temperature was 41.45° F.; 1 p. m., 58.33° F.; 9 p. m., 48.65° F. December was the coldest month, with an average morning temperature of 18.3° F.; noon, 34.5° F., and evening, 26.8° F; and June was the warmest month, with average morning temperature 58.6° F.; noon, 73° F., and evening 63.3° F. The large rivers are entirely free of ice in winter, but the small ones are covered by a thin crust. The soil freezes only at the surface.

The total population of Tibet has been estimated from the fantastic 33,000,000 down to 3,500,000, or even 2,500,000. The most reliable evidence indicates that Central Tibet has not more than about 1,000,000 inhabitants. Reliable statistics of the whole population were not obtainable, but it is certainly not very great, for the many narrow river valleys between high, rocky mountains are unfit for agriculture and could not sustain many inhabitants. Besides, the numerous unmarried ascetic ecclesiastics of both sexes, and epidemics of smallpox and other fatal diseases against which the Tibetans are almost defenseless, not only retard an increase, but would appear to gradually decrease the country's growth. More than 10 per cent of the population of Lhasa and neighboring monasteries died of smallpox in 1900. Further evidence of the limited Tibetan population appears from the fact that only about 20,000 monks from all the monasteries in the vicinity gather at the so-called "great Monlam of Lhasa." This, remember, in the center of Lamaism, where the principal sanctuaries and the higher Tszanite schools are located, which to a considerable extent are supported by the government! The native Tibetans call themselves Bo(d)-pa, and it is also customary to refer to people according to the names of particular regions. Thus the inhabitants of Tsang are called "Tsang-pa," etc. The floating population of the cities is composed of Chinamen, Nepalese, Kashmiris, and Mongols.

Most of the Chinamen, especially the emigrants from Ssŭ-ch'uan, are employed in the garrison camps of the large cities, while those engaged in commerce transact their small trade with the local inhabitants, principally the women * * * .

The Nepalese and Kashmiris, about equal in numbers, are merchants almost exclusively, though a few of the former are artisans. According to tradition the Nepalese were for a long time the architects of the temples, the sculptors of the Buddha statues, and the ikon painters of Tibet, and they are still the most expert cloth dyers, and are skillful as gold and silver smiths, from small trinkets to the gilt roofs of temples. The Buddhist Nepalese, in distinction from the ruling caste, Gurka, in

their Kingdom, are called Bä(l)-bo. They avoid marriage with Tibetans, for such ties mean death in their native land, and they therefore remain permanently in Tibet. The Kashmiris, on the contrary, always marry Tibetans, whom they first convert to Mohammedanism, and rear their children in that religion.

In administrative matters the Chinamen are responsible directly to the Amban, who resides and officiates at the southwest end of the city, near the ruins of the old city wall. The Nepalese and Kashmiris are subject to their elders, who serve as deputies in affairs before the central government of Tibet, with its jurisdiction. The Mongols, about 1,000 of them, are all monks, and only temporary residents, about 15 per cent of their number changing annually. They are distributed over the various monasteries according to their parishes. The Russian subjects among them in 1900 numbered 47, being Buriat Lamas from the region across the Baikal, with one Kalmuk from the Astrakhan government. They are subject to the monastery regulations.

The social classes are the nobility, the clergy, and the peasantry. The nobility consists of the descendants of former rulers of separate principalities and descendants of the fathers of Dalai Lamas and Panchens, who are invested by the Manchu court with the rank of prince of the fifth degree.

The princes, together with the monasteries and their parishes, are large landowners, and the peasants are serfs to them. The central government, or the Dalai Lama, owns, of course, more land and serfs than the classes named.

There is apparently no distinct military caste. Military service accompanies the privilege of special land grants, but we could not secure detailed information about it.

The houses are of stone or unburnt brick, cemented with clay. Most of those in the villages are one story high, while in the cities they are of two or three stories. The windows are without panes, or hung with cotton curtains, though in winter oiled native paper serves as protection from the cold. Fireplaces are used only for cooking. The houses have no chimneys, the smoke escaping as best it may through doors and windows, except that houses with upper stories have roof openings that somewhat alleviate the smoke nuisance, though equally a discomfort during rain. The principal fuel is dry manure of horned cattle and yaks. The clothing is of special design, made from native cloth in various colors. The poor classes wear white, the cheapest color; the richer people red and dark red, the soldiers dark blue, and yellow is used by higher dignitaries and princes. Women prefer the dark-red cloth. Of course, other colors are also met with. In proportion to their means, the Tibetans dress rather elegantly. Their jewelry is of gold, silver, corals, diamonds, rubies, pearls, turquoise, and other stones.

Tsamba, or roasted barley flour, mixed with either tea or barley wine, is one of the principal foods. The commonest vegetable is the radish. The favorite dish among all classes is "tsamtuk," a soup made by boiling zamba in water and flavored with bits of radish. Tsamtuk is best when made into broth with crushed bones, but it is comparatively expensive, and only the well to do can afford it every day.

The Tibetans are fond of raw meat, and when entertaining they serve meat either raw or not fully cooked. The principal meats are yak, mutton, and pig. Beef is not considered good, and ass and horse meat are not used at all. The poor classes also eat fish. We did not see the Tibetans use fowl as food, although they keep chickens for the eggs. Butter is much used, serving principally to whiten or flavor tea, and melted butter is burned in lamps before the idols. Sour milk, prepared also as thib-sho, is regarded as very noble food, and in poetry indicates something pure white.

Both sexes of all classes are very fond of barley wine, and owing to its cheapness and slight intoxicating properties it constitutes the principal beverage of the poor. The men are heavy smokers of leaf tobacco in pipes, and the monks, while avoiding the pipe, consume no less tobacco in snuff. Because of the high cost of tobacco, and to reduce its strength, the laymen mix it with the leaves of the plant "shol," and the monks use the ashes of ram and goat dung for that purpose.

The principal characteristics of the Central Tibetan may be described as stupidity and flattery, doubtlessly explained by the economic and political conditions of the country. They are also pious through fear of losing the protection of the gods or of angering them. On this account they have frequent sacrifices, bowing and circling before their sanctuaries. They are very impressionable and superstitious, and at each new episode in their lives they seek explanation from Lama seers and prophets, and when sick they prefer to take barley grains blessed by Lamas and prophets, or to have curing prayers read to them, rather than resort to medicine, which, by the way, is less developed in Central Tibet than in Amdo or Mongolia. Despite all, the Tibetans seem to be inclined to joviality, which manifests itself in song and dance during their frequent sprees and public holidays.

In their family life polyandry and polygamy exist, and the marriage of several brothers to one woman or of several sisters to one man are regarded as ideal relations. * * * Women enjoy perfect freedom and independence and take an active part in business affairs, often managing extensive enterprises entirely unaided.

Agriculture is the chief occupation of the settled population. Barley is the standard crop, from which tsamba is prepared; then comes wheat, for wheat flour; beans for oil, and peas, used by the poorer

class in form of flour, or crushed for horses, mules, and asses. The field work is done principally by "dzo" (a cross breed of yak and ordinary cattle), yaks, and asses. The principal beasts of burden are the small, hardy asses, and to some extent the ordinary horned cattle. Inhabitants of the highland regions are engaged in cattle raising, breeding yaks, sheep, and some horses. They use yaks for burden, and sheep in some places. The horse and mule are, to a certain extent, a luxury to the Tibetan, and are therefore kept only by the well to do. The native horses and mules are very small and homely, so that the rich people use only those imported from western China. In the stables of the Dalai Lama and Panchen there are blooded horses from India.

Commerce consists in supplying the cities and monasteries with agricultural products in exchange for articles of insignificant local manufacture and foreign import. The excess of domestic products is exported. The Tibetan has very few wants, chiefly limited to necessities, although some inclination toward objects of luxury, expensive ornaments, objects of cult and home adornment may be observed. The standard money is a silver coin valued at about 10 cents.

The unequal distribution of wealth and the subservience of poverty to wealth are conspicuous. There is such little commerce that labor is very cheap, the most expert weaver of native cloth receiving about 8 cents and board per day, while an unskilled woman or man laborer earns only 2 or 3 cents. The highest salary is paid to the Lamas, the prayer readers, who receive 10 cents a day for incessant reading. A house servant almost never receives pay beyond food and meager clothes. * * *

I will now describe the more or less prominent cities and monasteries visited in Central Tibet. Chief of all, of course, is the capital, Lhasa, sometimes called "Kadan" in literature, but both names have almost the same meaning—"the land of gods," or "full of gods." Its origin dates from the time of Khan Srongzang-Gambo, who lived in the seventh century, A. D. It is said that this khan had among his wives one Nepalese and one Chinese queen, each of whom brought along a statue of the Buddha Sakyamuni, to whose worship temples were erected in Lhasa, and he settled on Mount Marbo-ri, where the palace of the Dalai Lama now stands. Lhasa is situated on a broad plain, bordered on one side by the river U-chu and on the other by high hills. If we disregard the Potala, or palace of the Dalai Lama, the city is nearly round, with a diameter of about a mile. But the numerous orchards in the southern and western parts, the proximity of the Potala with the adjacent medical college, the court of Datsag-hutuktu, and the summer residence of the Dalai Lama led to the belief that it was about 25 miles in circumference. As a matter of fact, the circular road along which the pious make their marches on

foot or in prostrate bows is about 8 miles long. When these bows are faithfully performed the circle is completed in two days, making about 3,000 bows a day.

The orchards and trees in the outskirts of the city are admired by the natives, and give the place a very beautiful appearance, especially in the spring and summer, when the gilt roofs of the two principal temples glisten in the sun and the white walls of the many-storied buildings shine among the green tops of the trees. But the delight of the distant view at once vanishes upon entering the city with its crooked and dirty streets. * * *

A temple in which there is a large statue of Buddha marks the center of the city. The building is 140 feet square, three stories high, with four gilt roofs of Chinese design. The entrance gate faces the north. Each floor of the temple, with its blind external walls, is divided into numerous artificially lighted rooms, wherein stand various statues of Buddha. In the middle room on the east side stands the principal object of worship, Buddha Sakyamuni, under a sumptuous canopy. This bronze statue differs from the usual representations of the Indian sage in its head and chest ornaments of wrought gold set with precious stones, with a predominance of turquoise prepared and placed upon it by the famous founder of yellow-hat teachings, Tsongkapa. The face of the statue ever since the days of that same Tsongkapa has been kept painted by devout worshipers with gold powder dissolved in liquid glue. Upon long tables before the god, melted butter, offered by the worshipers, ever burns in golden lamps. Two other statues in the temple command almost equal respect—the 11-faced bodisattva Avalokiteshvara, of which the Dalai Lamas are regarded as incarnations, and the statue Pal-Lhamo, the protectress of women. * * * Under the latter statue barley wine is being incessantly sprinkled and grains are freely scattered. Abundance of food and snug hiding places in the folds of the clothing of the statue have attracted numerous mice, that are here considered holy. * * *

Besides the principal court of the temple there are two additional courts, in which the gatherings of the clergy of the neighboring monasteries are held.

Another small statue of Buddha stands in a temple in the northern part of the city and is called "Jovo-ramoche," but both temple and statue are inferior in proportions and ornaments to the main temple, and there is a noticeable difference in the reverence of the worshipers.

Within the city limits of Lhasa there are four courts or quarters of eminent Hutuktu incarnates, who were once Tibetan khans. They are the best buildings in the city, and as each has a certain number of pupils of the Lamas they are really small monasteries. Then, each

Lhasa, General View from the East.

LHASA, FROM THE NORTH.

of the eminent incarnates has his own inherited house. All other buildings belong either to the central government, or to the various communities of the neighboring monasteries. Buildings owned by private individuals are few and are mainly in the outskirts of the city.

All these buildings are under the control of the palace of the Dalai Lama, Potala, about two-thirds of a mile west of the city, and built upon a rocky height. The foundation of the palace, tradition says, was laid by the above-named Srongzang Khan during the seventh century, but it was remodeled, with the addition of the main central portion, called "Pobrang-marpo" (the red palace), during the life, and even after the death, of the fifth eminent Dalai Lama. It is evident that the palace and additions were planned to serve as a means of defense, and from this point of view Potala looms up as one of the old castles, of which many ruins abound in Tibet, and in the sad fate of which Potala played the preeminent rôle by subjecting them to itself.

The palace is about 1,400 feet long and about 70 feet high in front. The front and two sides are surrounded by a wall, the rear portion extending into the hill. In the construction of this palace the Tibetans displayed their highest architectural skill. Here are found the most precious treasures of Tibet, including the golden sepulchre of the fifth Dalai Lama, which is about 28 feet high. The treasures and apartments of the Dalai Lama are in the central portion of the temple palace, which is painted a tawny color and known as the "red palace" Pobrang-marpo. The remainder of the building serves as quarters for various attendants or followers of the Dalai Lama, including a community of 500 monks, the so-called "Namgyaltsan," whose duty it is to pray for the welfare and long life of the Dalai Lama.

Near the hill are the mint, the house for the Dalai Lama's subjects, the prison, and other structures. Upon the continuation of this hill stands the convent Mänbo-datsang, where 60 monks devote themselves to the study of medicine at the expense of the Dalai Lama. A little farther north is the idol temple of the Chinese Buddhists, and at the northwest foot of the hill is the palace of the fifth eminent hutuktu Kundu-ling, and about two-thirds of a mile west of the latter is the summer palace of the Dalai Lama.

There are in Lhasa two temples where mysticism is taught, with an attendance of 1,200 men.

The civilian population of Lhasa scarcely exceeds 10,000 persons, about two-thirds of them women, although the number may seem greater on account of the proximity of two large monasteries, the many transient visitors, and the gatherings of worshipers from lamaite countries. As the political and religious center of Tibet, its sanctuaries an attraction for numerous worshipers, Lhasa becomes an

important business place, as well as the connecting link in the commerce between India and northern Tibet and China with the East.

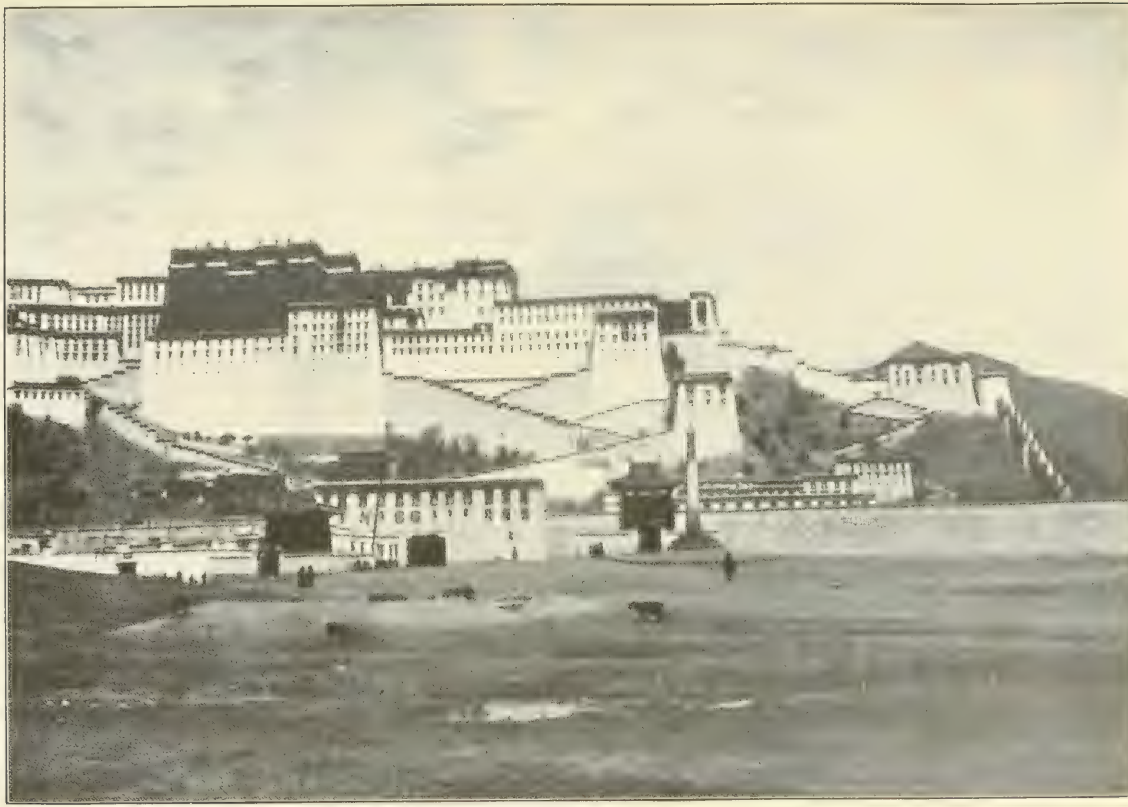
The market place is located around the central or temple section, where all the ground floors of buildings and open spaces in the streets are occupied by stores and small exhibits of merchandise. Women are preeminently the sales people, although in the stores of the Kashmiris and Nepalese men do the selling.

About the town stand the principal monasteries of Tibet, Sera, Brebung, and Galdan, known under the common name Serbre yesum. Brebung, the largest, is about 7 miles northwest of Lhasa; next comes Sera, about 2 miles north of the city, and last, Galdan, about 20 miles distant to the left of the river U-chu, on the incline of the steep mountain Brog-ri. They belong to one ruling sect of Tsongkapa and were organized during his lifetime, at the beginning of the fifteenth century. The Dalai Lama is regarded as the head of them all. There are 15,000 to 16,000 monks in all, of which 8,000 to 8,500 are in Brebung, 5,000 in Sera, and 2,000 to 2,500 in Galdan. In the Galdan monastery there is a vice-Tsongkapa, under the name, the "Galdan golden throne," a position established immediately after the death of the organizer, at the suggestion of his pupils and disciples. In olden times that office was filled by the choice of the Galdan monks, but on account of the confusion that followed elections the present method of installation was instituted, and the position is now filled in six-year terms by two Lamas, or, more correctly, wandering ecclesiastics, "Chzhuds," in the order of their service in the higher positions of their temple. The present incumbent is the eighty-fifth superior since Tsongkapa, or the eighty-sixth superior of Galdan, counting the reformer as the first.

Each of the monasteries has its laws and its own land, and they are thus independent of one another. The Brebung monastery is the most influential, because of its wealth and numbers, which are both the cause and the effect. Much of this superiority is also due to the fact that Brebung monks were elevated to Dalai Lamas, to whose lot it soon fell to be at the head of the spiritual and civil government of Central Tibet. The lamaiste monasteries are now not so much places of refuge for ascetics, as schools for the clergy, beginning with the alphabet and reaching to the highest theological knowledge.

It is true that the public school begins the instruction in religion, but the elementaries as well as the domestic occupations of adults are taught by private teachers chosen by the pupil. Nevertheless, every one, be he a boy five or six years old or a mature and even old person, is regarded as a member of the congregation and receives maintenance by becoming subject to the monastery laws. The principal subject taught is theological philosophy, which consists of five

LHASA. MOUNT MAR-BO-RI, AND THE PALACE OF THE DALAI-LAMA.



LHASA. POTALA, THE PALACE OF THE DALAI-LAMA FROM THE SOUTH.

sections of dogma, compiled by Indian pundits and translated into Tibetan. After the Tsongkapa reform, commentaries were made by various learned men upon those sections, which, according to the Lamas, do not differ in substance, all the commentaries adhering to the general idea of the teachings of the famous reformer. In the monasteries mentioned religion is taught from commentaries of six scholars in seven editions, each of which has a separate faculty. Three of these are Brebung and two each in Sera and Galdan.

Beside these religious faculties the first two monasteries have a faculty called "Agpa," to perform the mystic rites and to pray for the welfare of the monastery. The clergy is very unevenly divided in the various faculties. In Brebung, for instance, there are 5,000 men in one faculty and only 600 in the other.

It must be admitted that the monastic communities seem more concerned in securing "daily bread" than in the education of their members. Honors and degrees are conferred only upon those who endow the community in some practical manner. High positions, too, are encumbered with an obligation to distribute gifts among the members of the community. The principal source of endowments comes from the incarnates; that is, the incarnates of the soul of some predecessor. Whosesoever soul he may incarnate, he is recognized in the community as such only after he has distributed a certain amount of money and food. On the other hand, howsoever learned a monk may be, he receives the degree only after he has made endowments. Consequently charity and scholarship are measured by the amount of gifts to the monastery communities.

Each monastery has some special characteristic. Thus Brebung is famous for its prophets, Sera for its cells for the ascetics, and Galdan for various old curios.

The cult of the prophets or oracles is in its turn based upon the cult of the so-called "Choichong," or the guardians of learning. Judging by historical tradition it may be presumed that Buddhism, introduced into Tibet in the seventh century A. D., could not be rapidly developed because of difficulty in conquering the native gravitation toward their former deities, to which the people were accustomed and which were dear to them because they were their own creation. Besides, the sorcerers or priests were no doubt defenders of the old cult. On the other hand, however, Buddhism was protected by the rulers of Tibet and was bound to spread, and in the hard struggle popular superstition was granted some concessions. This compromise between Buddhism and sorcery was made, we are told, by a preacher of the ninth century, Padma-Sambava. He compelled the former local spirits to swear that henceforth they would defend Buddhist learning only, for which they were promised honors, rendered in the form of sacrifice of wine, barley seeds, etc. The highest of these spirits, which were

imported from India, are called "Idma," while those of lower rank are called simply "Choichong," or "Choisrung." The Choichong speak with the lips of the prophets whom they inspire. Only Choichong of lower degrees thus descend to prophets. As protectors and defenders of the faith the people imagine them to be horrible monsters in warriors' outfit. On this account the prophet, before the descent of "Choichong" upon him, dons a helmet and arms himself with spear, sword, or bows and arrows. The sense of the descent is contained in the fact that the spirit guardian of learning becomes incarnated in the chosen prophet for the sake of the living beings. Of such spirit guardians there are many, and the prophets are correspondingly numerous. The superior among them is the one confirmed by the Chinese Government—the Prophet Naichung-Choichong, whose gold-crowned temple and church suite is in the shady garden southeast of the monastery of Brebung. He is appealed to for prophecies, not only by ordinary mortals, but by all the higher clergy, including the Dalai Lama. Their mutual relation is as follows: Lama is "the abode of learning," and Choichong, its "guardian," having sworn to defend the religion vigilantly, will be honored of all for it. The Lama, therefore, honors—that is, brings sacrifices to—the Choichong, and the latter forestalls all that threatens the religion and the Lama, its representative. They constitute a check on each other and are allies at the same time. In this rôle of defenders of the faith the Choichong—or, more correctly, their prophets—wield a powerful influence over all classes. Their power is so great that even the Dalai Lama and the highest Hutuktu must reckon with them; they endeavor to incline all toward themselves. * * *

The "ritods," who are particularly numerous at Sera, are ascetic monks, who have retired from the world and buried themselves in meditation, which is regarded as one of the six means of attaining holiness—its origin based on Gautama's abdication of kingly luxuries in search of truth. The later ascetics choose obscure nooks in dense forests or dark caves in the rocks as places for meditation. More recently they have concerned themselves not only about their own attainment of holiness, but about the good of others, and their peaceful existence became distracted by the care of enlightening fellow-men. The silence of the cell for solitary meditations was broken by the cries of those hungry for knowledge, and to the lot of the ascetics fell the new care of their spiritual and material satisfaction. Then the idea of worldly vanity and comfortable quarters enticed the ascetics, and the cells were converted into comfortable dwellings, with quarters for pupils. The ascetic was thus transformed into the full master and ruler of his servants. Later on, with the appearance of the incarnates, the ritods become the inheritable property of the incarnates of the organizer, and several are transformed into separate monasteries.

FIG. 1.—LHASA. POTALA, FROM THE WEST-NORTHWEST.

FIG. 2.—LHASA. POTALA, FROM THE NORTH-NORTHEAST.

LHASA. GADAN KANSAR, THE PALACE OF THE OLD KING OF TIBET.

However, the people still revere the ritods, and the tombstones of some of them are coveted last resting places for the dead; upon them the corpses are cut up for the distribution of the flesh and bones among the griffin-vultures.

The relic curios, in which Galdan is rich, show us to what an extent the famous Tsongkapa took possession of the minds of his followers. His successor after his death sought memorials of the existence of the dear teacher, not content with his works. He did not believe that a teacher could pass away leaving no footprints, and search was made for these everywhere about the monastery he established—where he passed his last years. His searches did not end in failure, and in various groves and among the rocks he saw traces of the wonder of the teacher, and explained them by one or another incident in his biography, and, conversely, with his biography explained those traces. Frequently meditating about his idolized teacher, he drew and chiseled his image upon rocks, and the images of the Buddhas, his protectors. In course of time all these signs and statues made by the closest of pupils of Tsongkapa under the known influence of superstition began to be taken for wonderful relics and each worshiper began to venerate them.

It is characteristic that such relics are being discovered up to the present time. Thus the present Dalai Lama obtained from a rock a treasure, consisting of a hat and other articles, ascribed to Tsongkapa. He deposited the treasure in a special chest and placed it for safe-keeping at the sarcophagus of Tsongkapa and on its place erected a monument.

We will now briefly describe the other prominent monasteries and cities we visited. They are Tashilhunpo, and the cities of Shigatsze, Gyantsze, Samyé, and Tsetang.

The monastery of Tashilhunpo is about 170 miles west of Lhasa, to the right of the river Brahmaputra, on the south side of a mountain peak that forms an arm between that river and its tributary, the Nyangchu, and was established in 1447 by a pupil of Tsongkapa, Gedun-dru, who is regarded as the first incarnation of the Dalai Lama. There are about 3,000 monks within this place, divided into three religious and one mystical faculties. The head of the monastery is the incarnation of "Panchen erdeni," who maintains the monks there. Five stone idols and gilt roofs in Chinese style constitute the ornaments of the monastery.

About two-thirds of a mile northeast of Tashilhunpo, upon a separate rock, stands the castle Shigatsze, at the foot of which grew up a city of the same name, with a population of scarcely above 6,000 or 7,000. Here are stationed small Chinese and native garrisons. The castle itself is well known from the fact that during the conquest of Tibet in the middle of the seventeenth century by the Mongol

Gushi-khan it served as the residence of the governor of Tibet, Tszangbo, who, after a long resistance, was conquered and killed. The castle is now in a semideserted condition, and prisoners sentenced to die are thrown from its roof to the rock below.

About 50 miles from Shigatsze, in the valley of the Nyangchu, lies one of the old cities of Tibet, Gyantsze, which is a very convenient place on the commercial road to India from Lhasa and Shigatsze. From the religious standpoint it is famous for its great religious structure, Cho(d) den-gomang, five stories high, with many rooms and various objects of interest, especially ancient statues of Buddha. Commercially the city is known for the manufacture of rugs and cloths.

Up to the recent past the Tibetans made rugs of only one-colored wool in narrow strips, but now they weave, according to Chinese samples, continuous rugs with designs, which are much inferior in elegance to the Chinese, but in firmness much superior to them, as they are made of pure wool. We must assume that rug manufacture in Tibet could be considerably developed on account of the cheapness of labor and of sheep's wool.

The monastery of Samyé is on the left bank of the river Brahmaputra, about 65 miles southeast of Lhasa. It is the oldest of Tibetan monasteries, having been established at the beginning of the ninth century A. D. by the famous preacher of Buddhism in Tibet, Padma Sambava, and the Khan Tirsong-detszan. Its conspicuous feature is a five-story temple, a mixture of Tibetan and Indian architecture. The latter is evident by the fact that the top story is without columns, a feature so prominent in Tibetan style. This monastery, with its 300 monks, is maintained at the expense of the Dalai Lama treasury, and the idols are distinguished for their comparative cleanliness and care in the make-up.

About 20 miles east of Samyé, on the right bank of the river Brahmaputra, at the mouth of the fruit-producing valley Yarlung, lies the city of Tsetang (or Chetang), famed for the production of cloths, knitting, and the yellow monk hats. According to tradition, the first ruler of Tibet, Niatri-tszangbo, was found in the vicinity of this city and set upon the throne. The place occupies a favorable point on the road from Bhutan to Lhasa, as it enters the valley of the river Tszang. On the border of Bhutan lies the city of Tszona, where there is a market each spring that attracts many merchants from Lhasa.

Passing now to the government of Central Tibet, the dependence upon China is made evident by the Peking Court appointment of a Manchu resident to manage the higher government. At the head of the local self-government stands the Dalai Lama as the spiritual and secular head of Central Tibet.

FIG. 1.—THE MONASTERY GALDAGN IN TIBET.

FIG. 2.—THE MONASTERY TASHI-LHUMPO IN TIBET.

The Dalai Lamas attained their spiritual importance at the time of the Lama Gedun-Gyamtso, the superior of the Brebung monastery, who lived from 1475 to 1542. He was the superior simultaneously of the two monasteries Brebung and Sera, and during his life acquired such fame that he began to be regarded as the incarnation of his countryman, the famous organizer of the monastery of Tashilhunpo, Gedun-dru. But the custom of finding incarnates in youths begins after his death, and one officer of the castle proclaimed his son as this prophet's incarnation. This is evidently the first instance of the proclamation of an incarnate, and when he succeeded to the rights of his predecessor it was his fortune, worshiped almost from the cradle, to be invited by the Mongol, Altan-Khan, who gave him the title "Vajra-dara dalai-lama," which was sanctioned by the "Ming" Emperor of China. The significance of the Dalai Lama in Tibet, however, was at first not very great, which explains the recognition of the son of a Mongol prince as the fourth incarnate, who, it is true, was killed in the twenty-eighth year of his life in Tibet. The Mongols claim that the Tibetans killed him out of race hatred, and that they even cut him open as the Mongols kill sheep. His successor, Ag-vang lo-sang-Gyamtso, now called simply "Na-va-chenbo"—that is, the Fifth, the great—succeeded in acquiring the secular power, which at first was still only nominal. This Dalai Lama, in combination with the first "banichen," did not hesitate to invite Mongol arms to his country in order to conquer the detestable secular governors. Although they succeeded in accomplishing it, Tibetan affairs began to be interfered with either by Mongol princes, or those recognizing the superiority of the Manchu dynasty, or those who struggled for independence. After the death of the fifth Dalai Lama, for a period of forty years, the Dalai Lamas became the pretense of political intrigue of various power lovers until a series of historical events destroyed the power in Tibet of the Mongol and native princes, and until finally in the year 1751 the Dalai Lama was accorded the dominating power in matters religious and secular. The election of the Dalai Lama, up to the year 1822, the year of the election of the tenth incarnate, was based upon the prophecies of the highest Lamas and decision of the prophets, which is equivalent to an election by influential persons. But when the tenth incarnate was elected the system of the Emperor Tsien-lung, the casting of the vote by means of the so-called "serbum," or "the golden urn," was first applied. In this system the names of three candidates, determined by the former arrangement, are written upon separate tickets and placed in the golden urn. This urn is set before the statue of Jovo-Sakyamuni, and services are held there by deputies from the monasteries, praying for a righteous election. It is then carried over to Potala, to the palace of the Dalai Lama, and

there in front of a board upon which the Emperor's name is inscribed, in the presence of the highest authorities of Tibet and a deputation from the principal monasteries, the Manchu Amban, by means of two chopsticks, draws out one of the tickets. He whose name is written upon the ticket is placed upon the Dalai Lama throne. The election is confirmed by imperial decree, and the fortunate or unfortunate youngster is brought into the place with great honors. From this time on he is accorded appropriate honors and worshipers flock to him. In his youth he is taught reading and writing under the guidance of a special teacher—ioiu-tszini—selected from among the most learned famous Lamas. Then he is given a purely religious education, following the above-mentioned five sections with all their seven commentaries. For practical disputes one learned Lama is detailed from each of the theological faculties of the three principal monasteries. These instructors are called Tszang-skab-khanpo. Our Buriat countryman, Agvan Dorchzheyev, was one of these with the present Dalai Lama.

After finishing the course of instruction he receives the highest degree in theology in the same manner as the other Lamas, but, of course, with a more liberal distribution of money to the monasteries and more careful questions on the part of the learned Lamas who dispute with him and who are appointed in advance. After this, when 21 to 22 years old, the Dalai Lama enters the ripe and independent existence. Since 1806 five Dalai Lamas have reigned. The present incumbent, the thirteenth, Tubdan-Gyamtso, was born in 1876, so that now he is 27 years old. About six or seven years ago he had a struggle with his regent, most famous of Tibetan hutuktu, "Demo," and came out victor, which no doubt saved him from the fate of his four predecessors, who perished at various ages, frequently the result of violence inflicted by regents or representatives of other parties that were striving to remain longer close to the "power." The present Dalai Lama accused Demo of organizing plots against his life, confiscated his immense wealth, and placed him under a rigid home arrest in a separate room, where Demo was discovered suffocated one beautiful morning in the autumn of 1900. The Dalai Lama assumed the head rule of Tibet, and one of his conspicuous acts is the abolition of capital punishment, which was practiced extensively by the regents. It seems in general that he is very energetic, and inclined to be a good man, with considerable love for knowledge.

The second person of the lamaist hierarchy is the Panchen-Erdeni, who lives in a monastery in the provice of Tashilhunpo Tsang. The first Panchen-Erdeni was the Lama Lobzang Choigyi-Gyaltsan, who was born in 1570. This earnest Lama was the instructor of the fourth and fifth Dalai Lamas, when he played an important rôle in political affairs, which served to enhance the power of the Dalai Lama. The official title, Panchen-Erdeni, and the imperial diploma and seal was

granted only the third Panchen, Pande-yéshé, in 1870 at an audience at Peking. At present the sixth incarnate lives; he was born in 1882, and is therefore 20 years old.

The Panchen is next to the Dalai Lama in official capacity, but in the supervision of the lamaists he is considerably above him, because of his holiness. Especially is he regarded as the future king of the holy world "Shambala," in which he will be the principal leader.

It is customary to call the Dalai Lama also "Chyab-gong thamchäd-mkhen-pa" (the omniscient—the object of faith), but the Tibetan applies this name to every eminent Lama incarnate he respects, since the charm of the Dalai Lama, as a holy individual, is less effective upon the religious feeling simply because of his distance than that of a Lama more easily approached, to whom he can appeal more often with inquiries relative to his religious requirements. The Dalai Lama, therefore, is known at places distant from Lhasa only as the principal ruler of Tibet, while the religious sentiment of the laymen is directed toward their patron, regardless of the sect to which he belongs.

The teachings of Tsongkapa now reign supreme in Central Tibet, but after the struggle during the first period of their introduction they are now entirely reconciled and to a certain extent are indifferent toward other sects. The contemporary lamaist in general and the Tibetan in particular regard the objects of faith of the various sects with exactly the same reverence. Even the central government of Tibet, with the Dalai Lama at its head, frequently bows before the representatives of the old red-hat sect (the yellow-hat sect predominates now). The laity does this, of course, out of ignorance and superstition, but such explanation does not apply to the higher representatives of the yellow-hats, who are guided by Tsongkapa's way of looking at the world and possess a knowledge of the difference in the views of other sects. We believe that the conduct of these men toward other sects is inspired by political motives, the desire to satisfy the superstitious requirements of the populace, and to be vindicated in case of popular suffering and unfortunate political events.

The central government of the land is in the hands of a council presided over by the Dalai Lama, called "deva-dzung." The principals in this council are four "kalons," or dignitaries, appointed by the Chinese Emperor, and their meetings are held in a special office—"kashag," or executive house. They are appointed from prominent aristocratic families, three of them civilians, the fourth a clergyman. For the local administration governors are sent from the "deva-dzung," usually two in number with equal powers—one a clergyman, the other a civilian. Districts are frequently leased, the lessee ruling according to established custom, being obliged to pay into the treasury a certain sum of money or to pay in kind. Usually these lessees are members

of the higher administration, and they send their own representatives into the districts.

Of late the central government has apparently begun to strive to accumulate land, for which purpose it takes away strips of land from the monasteries under various pretenses or makes purchases on installment from the annual income.

The affairs of Tibet in general are ruled by the hereditary aristocracy, whether it be the son who inherits his father's rights or the incarnate who inherits the rights of his predecessor. As the born aristocracy lives in strict isolation, not mingling with the common people, the central government, despite its deliberative character, may be called an aristocratic oligarchy.

We stated that the Dalai Lama is the head of the central government. The question arises, Who takes his place in the interim between his death and the election of a new incarnate and until the latter becomes eligible? This question arose for the first time in 1757, after the death of the seventh Dalai Lama, and was solved by the appointment of a regent by the Chinese Emperor under the official name "the director of the Dalai Lama's treasury," with the title "nomun-khan." In writing, the Tibetans refer to him as "the Khan's viceroy" and in their daily conversation simply "the Tibetan khan." The first man appointed to the regency was the very eminent hutuktu "Demo," after whom other hutuktu were appointed.

The tribunal and, in general, all administrative affairs are based on bribery, court examinations, on torture by means of lashes and similar methods, cauterization by means of burning sealing wax being regarded as the most severe. The punishments are execution by drowning, imprisonment, banishment with giving away into slavery, blinding, amputation of the fingers, lifelong fetters and foot stock, and lashes.

The permanent army, maintained by the treasury, consists of 4,000 men. Its armament consists of spears, matchlock guns, and bows. For the protection of the body they have a helmet ornamented with feathers, a small plaited shield, and some wear armor. They are officered by "daipons," appointed from the higher aristocracy. The soldiers usually live in their homes in the villages and only periodically gather at posts, where they are inspected and taught to fire blank charges, and the use of the bows. The army is divided into cavalry and infantry. Despite the tendency of the Tibetans in the eastern provinces to indulge in pillage and highway robbery, the central Tibetan dislikes to make war; he is much more peace loving and more inclined toward peaceful labors, on account of which he regards military duty as superfluous and interfering with domestic pursuits. One frequently sees soldiers on the way from an inspection spin wool, stitch shoes, turn a prayer wheel, or repeat their chaplet.

Speaking about the East Tibetan robber tribes, we must say they try to prey upon the goods of others without bloodshed, threatening only the cowards. As soon as they see that the intended victims are determined to show serious resistance, they escape to their quarters. If one band of robbers strips a victim of everything, another band will clothe him and supply him with food.

The monasteries are governed by their own laws, administered by their own elders, the highest of which in the principal monasteries are appointed by the Dalai Lama. Discipline and the whole régime is based on "the fear of the governors." This fear must be manifested even on the street; a monk must not show himself before them on the street. When, on very exceptional occasions, he does meet them, he must lie down, wrap his head in his hood, and lie motionless as if dead. Justice is also based principally on bribery, and the punishment is banishment from the monastery with a fine of money and lashes. The material condition of plain monks in Tibet is so bad that the convicted always prefers the punishment of the lash to fines.

The foreign relations of Tibet are conducted with British India through Bhutan; with Kashmir through Ladak, and directly with Nepal, China, and Mongolia.

Tibet imports from India, English materials, principally cheap cloths, enameled vessels, teapots, plates, and cups; objects of luxury, as coral, amber, brocade; medicine and dye stuffs; and various English trinkets, such as mirrors, beads, jars, matches, penknives, etc. All these articles are imported by native Bhutanese, Nepalese, Kashmiri, and Chinese merchants. In general, the Tibetans are of late becoming more and more fond of English products; the English rupees, too, are beginning to compete with the local coinage. The things exported to India are yak tails, sheeps' wool, borax, salt, silver and gold, yaks to a certain extent, and horses and mules brought over from northern China.

From China the Tibetans import tea, which they love so well, chinaware, cotton and silk fabrics. From northern China, mules and horses are imported, and, to a limited extent, breeding asses.

For use by the Chinese, Tibet exports little, and the considerable amount of native manufactured articles, together with those imported from India, that are exported there go to satisfy the demands of the Mongol lamaists.

The articles exported are various objects of cult, as small statues, painted images, religious books, and prints made from carved wooden blocks, incense candles, ribbons, peacock feathers, leaf-shaped seeds "tsampaka," and similar articles that bring high prices only because of the piety of the Mongol lamaist and his reverence for holy things from Tibet. The more famous the person that produces these articles

the more eagerly they are purchased and the higher is the price paid. But Tibet also has a trade in cloths, in knit goods, and in the yellow hats of the ecclesiastics, and this class of traffic, which depends upon the religious sentiment of the purchasers, as is the case with presents to Tibetan lamas, attains a considerable sum annually. The commerce in ordinary merchandise, however, scarcely exceeds $60,000.

Since objects of cult are exported to Mongolia and since only the treasuries of incarnates and monasteries possess capital, the commercial caravans are fitted out exclusively by the treasuries of the Dalai Lama or other rich incarnates and by monastery communities. The responsible officers of the caravans are called "tsonpons." The "tsonpons" sent out by the Dalai Lama must double the original capital in three years' time, which capital is estimated at a very inflated appraisal of the goods. Each succeeding "tsonpon" is the auditor of his predecessor—that is, he sees that the contract is fulfilled.

Here and there the merchants in Mongolia, besides their commercial operations, make collections of contributions for one or another enterprise of a monastery or an incarnate. If we add to this those immense sums that are being collected by famous and infamous lamas, whether they be invited to Mongolia or are there of their own accord, we can safely say that Mongolia to a considerable degree enriches Tibet.

Up to a very recent period there were no relations between Tibet and Russia, although Buriats, who are Russian subjects, have for a long time made secret pilgrimages to Tibet, fearing oppression from the Russian administration, and entered Tibet under the assumed name of "Khalkhas" Mongols, fearing exclusion as foreigners. About fifteen years ago "Khalkhas" and Buriats belonging to one community in Brebung quarreled for some reason, and the former called the latter "Oros," or Russians. The matter reached the highest authorities, and, thanks to the able management of the affair by the Buriat lamas, it was established that, although the Buriats are Russian subjects, they are followers of the yellow-hat religion. The Khalkhas who raised the matter, having lost the trial, was obliged to leave the monastery, and the others received warning that they would be fined 5 lans (about $4) every time they call the Buriats "Oros." Russia can hardly hope to obtain a profitable market for her goods in Tibet, but it will pay her to establish relations with Tibet because it is the center of lamaism, to which are chained the thoughts of contemporary Mongols, of whom there are about half a million, under the names of Buriats and Kalmuks, who are Russian subjects.

A JOURNEY OF GEOGRAPHICAL AND ARCHÆOLOGICAL EXPLORATION IN CHINESE TURKESTAN.[a]

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In June, 1900, the government of India placed me on a year's special duty in order to enable me to carry out a long-cherished plan of archaeological explorations in the southern portion of Chinese Turkestan and particularly in the region of Khotan. Many previous antiquarian tours in Kashmir, the Punjab, and on the fascinating ground of the northwest frontier of India, had taught me the necessity of close topographical observation as an important adjunct of historical research in those fields toward which, as an Indian archæologist, I felt most attracted. It was hence clear to me that the task awaiting me in Chinese Turkestan would have to comprise also surveying operations, such as are required for the accurate fixing of the position of ancient sites, and generally for the elucidation of the historical topography of the country. But in addition I was anxious from the first to avail myself of the opportunities the journey might offer for geographical work of a more general character in regions that had so far remained without a proper survey or altogether unexplored.

The generous aid accorded to me by the Indian survey department made it possible to carry on a continuous system of surveys, by plane-table, astronomical observations, and triangulation, throughout the course of my journey. Its results have been embodied in maps which are shortly to be published by the trigonometrical branch of the survey of India. These maps, as well as the detailed report of my explorations on which I am at present engaged under the orders of the India government, will, I hope, show that I have spared no efforts to utilize the opportunities offered to me in the interest of geographical science. In the meantime, it is a source of sincere gratification to me that I am enabled, by the courtesy of your council, to place this succinct account of my journey and labors before the Royal Geographical Society, which, since the days of those great scholars, Sir Henry Rawlinson and Sir Henry Yule, has done so much to clear the way for the critical study of the ancient geography of India and Central Asia.

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The plan of archæological explorations about Khotan, and of the journey that was to lead to them, was first suggested to me in the spring of 1897, by a series of remarkable antiquarian acquisitions from that region. Among the papers left behind by that distinguished but ill-fated French traveler, M. Dutreuil de Rhins, there were found fragments of ancient birch-bark leaves, which had been acquired in the vicinity of Khotan, and which proved to contain a Buddhist text in an early Indian script and language. On publication they were soon recognized as the oldest then known Indian manuscript, going back to the first centuries of our era. About the same time the "British collection of Central Asian antiquities," which had been formed at Calcutta with the assistance of the government of India in the foreign department, and under the care of Doctor Hoernle, the eminent indologist, received from the same region very notable additions consisting of manuscripts, ancient pottery, and other remains. These objects had been sold to the political representatives of the Indian government in Kashgar, Kashmir, and Ladak, as finds made by native "treasure seekers" at ancient sites near Khotan and in the neighboring portions of the Taklamakan Desert. A curious feature of these acquisitions was that, besides undoubtedly ancient documents in Indian and Chinese characters, they contained a large proportion of manuscripts and "blockprints" in a surprising variety of entirely unknown scripts. While the materials thus accumulated, no reliable information was ever forthcoming as to the exact origin of the finds or the character of the ruined sites which were supposed to have furnished them.

No part of Chinese Turkestan had as yet been explored from an archæological point of view, and, however much attention these discoveries attracted among competent European orientalists, it was evident that their full value for the ancient history and culture of Central Asia could never be realized without accurate researches on the spot. The practicable nature of such investigations was proved by the memorable march which Dr. Sven Hedin had made in the winter of 1895–96 through the Taklamakan Desert northeast of Khotan, and of which the first accounts reached me in 1898. It had taken the famous Swedish explorer past two areas of sand-buried ruins, and, though his necessarily short halt at each had not permitted of any exact evidence being secured as to the character and date of the ruins, this discovery amply sufficed to demonstrate both the existence and comparative accessibility of ancient sites likely to reward excavation. * * *

By the middle of April, 1900, I was at last able to leave steamy and overcivilized Calcutta for Kashmir, where I completed the outfit and transport arrangements needed for my camp. The many tours I had made during previous years through the mountains in and about Kashmir had furnished me with sufficient practical experience to enable

me to anticipate with fair accuracy the conditions of transport and supplies on a great part of the travels before me. The government of India had granted me permission to use the route through Gilgit and Hunza for the journey to Kashgar, which was to form my proximate goal. By the end of May the snow on the mountain ranges between Kashmir and Gilgit had melted sufficiently to make the attempt of crossing the passes with laden animals just practicable. By that time, too, the subsurveyor's little party, and another Turki servant sent by Mr. Macartney, the British political agent in Kashgar, had joined me, and all requisite stores and equipment had been duly collected and packed. Owing to the quantity of scientific instruments, photographic glass plates, etc., to be carried, and to the provision that had to be made for stores of all kinds in view of the distances likely to separate us thereafter from civilized "bases of supply," my caravan numbered 16 baggage animals when it set out on the morning of May 31 from Bandipur, the little port on Volur Lake and the starting point of the "Gilgit Transport Road."

Though the snow still lay deep and the weather was trying, the Tragbal and Burzil passes (approximately 12,000 and 13,000 feet above the sea, respectively) were crossed without mishap. Pushing on by rapid marches through the Dard valleys of Astor, imposing in their barren grandeur, and across the rock-bound bed of the Indus near Bunji, we reached the Gilgit cantonment on June 11. Fresh transport arrangements necessitated a short halt at this last outpost of Anglo-Indian civilization. Thanks to the kind offices of Capt. J. Manners Smith, V. C., C. I. E., then political agent at Gilgit, I was there able not only to make good various small defects in the equipment of my caravan, but also to collect interesting information concerning the customs and traditions of the Dard population inhabiting these valleys. The Dards deserve, indeed, to be treated with respect by the historical student and ethnographist, for their tribes have clung to this forbidding ground of bleak rocky gorges and ice-crowned ranges ever since the days of Herodotos. Ancient, like the mountains themselves, looks the race, with its sharply defined ethnic characteristics and language.

On June 15 I started from Gilgit filled with a grateful recollection of the kind help and hospitality which I had enjoyed among the last British officers I was to see for some time. Marching round the mighty buttresses of Mount Rakiposhi (with its highest needle-like peak soaring to an elevation of over 25,000 feet) and through mountain scenery that under a sky of dazzling clearness looked as grand as any I have ever seen in the Himalaya, we passed on the third day into the territory of the chiefs of Hunza and Nagir. Close to the hill fort of Nilth, famous for the brilliant little campaign of 1891, I visited with interest the deep-cut gorge descending from a glacier of Rakiposhi, where Captain Manners Smith climbed the most precipitous cliffs with his

handful of Gurkhas and Dogras, and, finally breaking the resistance of the Kanjuti hill men, won his Victoria cross. It was pleasant to note that the brave mountaineers who were vanquished here looked back upon this daring exploit of their quondam foe and conqueror with almost as much pride as if it had been performed by their own side. A short distance higher up the valley, near the village of Thol, I noticed a well preserved little stupa, a monument of those early centuries when this secluded valley, like the rest of the difficult hill tracts farther west, held a population attached to Buddha's faith. Was it the same small Kanjuti race, puzzling by its complete isolation in regard to language and ethnic origin, which now occupies Hunza?

At Aliabad, near the capital of the Hunza chief, I spent two days busily occupied with the rearrangement of all loads for transport by coolies; for the difficult mountain tracks by which alone the Taghdumbash Pamir can be approached during the summer months, from the side of Hunza, are absolutely impassable for any beast of burden. Acting on the instructions kindly sent in advance by the political agent at Gilgit, Wazir Humayun, the energetic chief adviser of Muhammad Nazim, the present Mir of Hunza, had made ample preparations for the trying route ahead. It was difficult to realize that this little mountain chieftainship was, until ten years ago, by reason of the freebooting and slave-raiding expeditions which it sent forth and Wazir Humayun himself had led more than one successful raid of this kind—the terror of all neighboring regions.

On June 20 I moved my camp to Baltit, where I paid a return visit to the Mir in his old and highly picturesque castle. I was interested to note in the carved woodwork of mosques and other structures decorative elements of ancient Indian type, while in the furniture and fittings of the Mir's residence modern central Asian and Chinese influences were plainly discernible. On the following day we commenced on foot the series of trying marches up the gorge of the Hunza River. The winter route, which crosses the river bed at frequent intervals, had become wholly impracticable, owing to the melting snows and the swollen state of the river. The precipitous mountain spurs and the great glaciers descending to the left bank of the river had daily to be crossed by tracks which may rightly be described as a succession of Alpine climbing tours of a decidedly tiring nature. They often led over narrow rock ledges and by rough ladder-like galleries (rafīk) along the faces of cliffs, where the carrying of loads would be nervous work for any but such extraordinarily sure-footed and active hill men as the people of Hunza. Frequent enough were the places where even my little fox terrier, accustomed to rough climbs from many a tour with his master, had to be picked up and carried.

Toiling along these precipices, amidst scenery truly inspiring in its rugged splendor, I was often reminded of the vivid accounts which

Fa-hien and other ancient Buddhist pilgrims from China have left us of their experiences on the journey through the gorges of the Indus. From Ghulmit, the second stage onward, the scanty settlers occupying the few patches of cultivated ground in the valley proved to be of Iranian origin, speaking a Wakhi dialect closely allied to that which is used by the Wakhan immigrants found in Sarikol. Thus, in this part of the Hindukush, too, the line of contact between the great areas of the Indian and Iranian families of language does not completely coincide with the geographical watershed.

After six days spent in more or less continuous climbing, Misgar, the northernmost hamlet of Hunza, was reached, where I was able to discharge the hardy hill men who had carried our impedimenta without the slighest damage over such trying ground. On June 28 at last I crossed, by the Kilik Pass (circ. 15,800 feet above the sea), into Chinese territory on the Taghdumbash Pamir, using the yaks of the Sarikoli herdsmen, who, by Mr. Macartney's arrangement with the Chinese authorities, had awaited me at the southern foot of the pass.

From Köktörök, our first camp on the Taghdumbash, at an elevation of over 14,000 feet, we commenced our plane-table survey, on the scale of 8 miles to the inch. Throughout our travels in the mountains I endeavored to supplement it, as far as my limited time permitted, by photogrammetric work, for which I used the excellent Bridges-Lee photo theodolite kindly lent to me by Mr. Eliot, the head of the Indian meteorological department. Systematic triangulation by theodolite was started at the same time with the help of the points supplied by the surveys of the boundary commission and Captain Deasy, while regular astronomical observations for latitude were made by Babu Ram Singh from here onward at all camps, the exact determination of which possessed topographical interest. The constant and direct supervision which I exercised over the plane-table work enabled me to pay special attention to the local nomenclature. A good deal of philological and historical interest attaches to the latter in regions like the Pamirs and a considerable portion of Chinese Turkestan, over which have passed the waves of great ethnic migrations. I believe, therefore, students interested in this part of central Asian geography will derive some advantage from the pains I took to correctly ascertain and to record with phonetic accuracy all local names throughout the territories covered by our surveys.

From the height of the Khushbel peak, the first "hill station" of our survey (close on 17,000 feet above the sea), I could simultaneously see the ranges which form the watershed between the drainage areas of the Indus, the Oxus, and the Yarkand rivers, and which politically divide the territories of British India, Russia, and China, Afghanistan (pl. I). Pressed for time, as I necessarily was in regard to all that

touched my topographical interests, I could not resist the temptation of pushing westward, at least as far as the Wakhjir Pass, which leads from the Taghdumbash Pamir to the headwaters of the Oxus. Camping close to the summit of the Wakhjir Pass (circ. 16,200 feet), I visited on July 2 the head of the Ab-i Panja Valley, near the great glaciers which Lord Curzon first demonstrated to be the true source of the river Oxus. It was a strange sensation for me in this desolate mountain waste to know that I stood at last at the eastern threshold of that distant region, including Bactria and the upper Oxus Valley, which, as a field of exploration, has attracted me ever since I was a boy. It was the threshold only I had reached, and I knew that this time there was no entrance for me into the forbidden land. Notwithstanding its great elevation the Wakhjir Pass and its approaches, both from the west and east, are comparatively easy. Comparing the topographical features with the itinerary indicated by Hiuen Tsiang, the great Chinese pilgrim, I am led to conclude that the route which he followed when traveling, about A. D. 649, on his return from India, through the valley of Pa-mi-lo (Pamir) into Sarikol, actually traversed this pass.

As I marched down the gradually widening valley of the Taghdumbash Pamir toward Tashkurghan, the chief place of the Sarikol district, I fully realized the contrast which its expanses of comparatively rich grazing offer to the rocky destitution of the Hunza gorges. Increasing numbers of nomadic herdsmen, both Kirghiz and Wakhi, now frequent the valley, which was an utterly deserted waste, and rarely used, even as a route, while there were Hunza raiding parties ready to swoop down from the mountain fastnesses southward.

I also felt glad to be once more on the track of Hiuen Tsiang, whose footsteps I had traced to so many a sacred Buddhist site of ancient India. The position and remains of Tashkurghan were found to agree most closely with the description which Hiuen Tsiang and the earlier Chinese pilgrim, Sung-yun, give of the capital of the ancient Kie-pan-to. The identification of the latter territory with the modern Sarikol, first suggested by Sir Henry Yule, was thus fully established. The ruined town, which extends round the modern Chinese fort of Tashkurghan, and still shows a quadrangular inclosure of crumbling stone walls, "rests on a great rocky crag, and is backed by the river Sita" (i. e., the Yarkand River), on the east, exactly as the pilgrims describe it. As a striking instance of the tenacity of local tradition, it deserves to be mentioned that I found the curious legend which Hiuen Tsiang relates of the princess imprisoned in ancient days on a rock fastness still clinging to the identical locality of this valley.

I believe that Tashkurghan, as an historical site, has claim to even greater antiquity than that implied by the notices of Hiuen Tsiang and Sung-yun. Nature itself has plainly marked it not only as the

administrative center for the valleys of the Sarikol region, but also as the most convenient place for trade exchange on an ancient and once important route connecting great portions of Central Asia with the Far East and West. Judging from local observations, everything tends to support the view first expressed by Sir Henry Rawlinson that Tashkurghan, "the stone tower," retains the position as well as the name of the *λίθινος πύργος*, which Ptolemy and, before him, Marinus of Tyre, the geographer, knew as the emporium of the extreme western frontier of Serike—i. e., the Central Chinese dominions. From Tashkurghan the road lies equally open to Kashgar and Khotan, and thus to both the great trade routes which led in ancient times and during the Middle Ages from Turkestan into the interior of China. At Tashkurghan, also, the two best lines of communication across the Pamirs converge, the Taghdumbash Valley, which gives access to the upper Oxus, being met here by the route which leads over the Naiza-Tash pass toward the "Great Pamir" and thence down to Shighnan.

In order to extend our survey over ground that was geographically interesting, I chose for our further march to Kashgar the route which passes through the high valleys between the Russian Pamirs and the western slopes of the great transverse range of Muztagh-Ata. On July 13 I had reached the shores of the "Little" Karakul Lake, at the northern foot of the "father of ice mountains," and about 11,000 feet above sea level, where I found a fairly large encampment of nomadic Kirghiz. The ample supply of sturdy yaks which we obtained from them greatly facilitated transport arrangements. It thus became possible within the comparatively short time available to establish a series of excellent survey stations on various high spurs descending from Muztagh-Ata. They enabled us to extend the triangulation brought up from the Taghdumbash to the great glacier-crowned ranges facing Muztagh-Ata from the north and northeast and overlooking the "Little" Karakul Lake. (Pl. I.)

Their main peaks, though rising to over 23,000 feet, remain below the elevation of Muztagh-Ata. Yet these mighty walls of ice and snow, stretching their crest line of dazzling whiteness for a distance of at least 24 miles, and streaked by numerous great glaciers, appeared perhaps even more awe inspiring than the grand ice-girt dome of Muztagh-Ata itself (pl. II). Our stay in the midst of this mountain world fell in what was probably the most favorable season; yet the hours when any considerable portion of the panorama was clear of clouds and driving rain or snow were few indeed. Notwithstanding the rapid changes of the atmospheric conditions and the difficulty of working a delicate instrument on heights ever exposed to cutting winds at temperatures that readily fell below freezing point, the Bridges-Lee phototheodolite proved very useful for recording topographical details. From the rounds of phototheodolite views which were secured by me

at a series of excellent survey stations, Lieutenant Tillard, R. E., of the trigonometrical branch office of the survey of India, succeeded in constructing a map of the Muztagh-Ata region on the enlarged scale of 4 miles to the inch, which shows much additional detail. It will be published along with the general map embodying our survey. But both the taking of the phototheodolite views and the working out of the results has absorbed a great amount of time and labor, and reference to the plane-table sections has, I believe, often been found indispensable in plotting.

For the purpose of the phototheodolite survey, and also in order to gain some closer personal experience of the "father of ice-mountains," I made on July 18–19 two ascents on the western slopes of the central mass of Muztagh-Ata. The route chosen lay up the ridge which flanks the Yambulak glacier from the north, and, as seen from below, seemed to ascend unbroken to the northern of the twin peaks of the great mountain. It was by the same route that Dr. Sven Hedin, in the course of his explorations of 1894, had reached his highest point. But since the visit of the great Swedish traveler, the physical conditions on the surface of the ridge seem to have undergone a considerable change for the worse. At the time of his ascents the ridge appears to have been bare of snow up to an elevation estimated at over 20,000 feet, and consequently it had been possible to use yaks both for riding and transport. I found the ridge from about 15,500 feet upward enveloped by heavy masses of snow, which seem likely to transform themselves gradually into a mantle of ice, such as lies over the other elevated slopes of the mountain. Only on the very edge of the precipitous rock wall by which the ridge falls off toward the Yambulak glacier small patches of rock protruded here and there from the deep snow. Above 17,000 feet even these disappeared, and at about the same height it was necessary to leave behind the yaks, which, foundering constantly in the deep snow, had become useless.

On the opposite side of the glacier the southern wall of rock is topped by a thick layer of ice to a far lower point, and consequently little avalanches would be seen gliding down from it as the day wore on. Luckily, on our side the glittering snow sheet over which we ascended seemed to rest as yet firmly on the rock. The weather was by no means favorable, and on the second day we had to contend with frequent gusts of violent wind, and with occasional showers of snow. The maximum elevation I then reached was, by the evidence of the hypsometrical readings, within a few feet of 20,000 feet. It had taken nearly eight hours of constant toil to attain it from my camp, pitched at an elevation of over 15,000 feet. The couple of Kirghiz who could be induced to set out with us were, curiously enough, first seized by mountain sickness, and had to be left behind with their yaks. At an elevation of about 19,000 feet, Ram Singh, the subsurveyor,

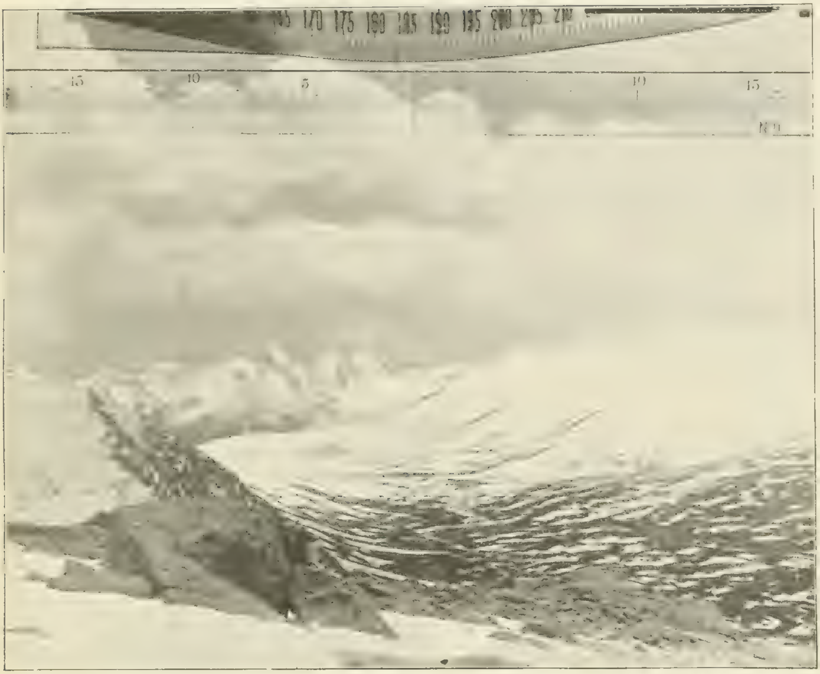


FIG. 1.—PHOTOTHEODOLITE VIEW OF KILIK PASS, FROM KHUSHBEL PEAK.

FIG. 2.—ICY RANGES NORTH OF MUZTAGH-ATA, SEEN FROM LITTLE KARAKUL.

FIG. 3.—MUZTAGH-ATA, SEEN FROM LITTLE KARAKUL.

FIG. 4.—PEAK "KUEN-LUEN NO. 5" (OR "MUZTAGH"), SEEN FROM NORTHWEST, WITH RANGES ABOVE YURUNGKASH GORGE ON RIGHT.

was obliged to stay behind, overcome by headache and lassitude. Next Ajab Khan, the active Puniali, who had accompanied me as an orderly from Gilgit, fell out, and ultimately only the two splendid men of the "Hunza levies," who had been selected for me by the Mir of Hunza, and had proved most useful as guides, plodded on with me.

The previous day, while engaged in phototheodolite work, I had sent them ahead to reconnoiter the ridge. Excellent climbers as they are, they had then reached a point apparently about 2,000 feet higher up. Their progress was there stopped by a sheer precipice of impassable rocks descending to what I conclude to be a transverse glacier previously hidden from view, separating the great ridge we followed from the main mass of the northern summit, and communicating northward with the Kampar-kishlak glacier. Owing to the threatening aspect of the weather, I had to forego the attempt, which our bodily condition would have otherwise well permitted, of reaching this farthest accessible point of the ridge. I was thus unable to judge with my own eyes of the true mountaineering difficulties that would have to be faced in the event of a systematic effort being made to climb the northern summit from this side. An ample allowance of time, a good Swiss guide or two, and a sufficient number of hardy Hunza mountaineers to carry loads, would seem to me indispensable provisions for such an effort.

As we descended, the clouds lifted toward the west and revealed a panorama vast and impressive beyond description. It extended practically across the whole breadth of the Pamir region. Far away to the southwest it was bounded by glittering pinnacles, in which I could recognize the mountain giants that guard the approach to the Indus Valley. They had worthy rivals to the north in some towering masses of ice and snow, which I could not fail to identify with Mount Kaufmann and other great peaks of the trans-Alai range.

The night, which I passed uncomfortable enough in my tent, pitched with difficulty at an elevation of about 16,500 feet, brought fresh snow with driving gales, and after vainly waiting next day for a change, I was forced to descend once more toward Lake Karakul. Before leaving this inhospitable, yet so fascinating, neighborhood, I had the satisfaction to ascertain that the Kirghiz legend of a hoary saint (Pir) mysteriously residing on the inaccessible heights of the great ice mountain, still retains distinct features of the "old story" which Hiuen Tsiang heard of the giant Buddist hermit who was seen entranced "on a great mountain covered with brooding vapors," evidently identical with Muztagh-Ata.

On July 23 I started down on to the plains of Kashgar by the route of the Gez defile. Owing to the collapse of one of the bridges in this remarkably narrow and difficult gorge, I was obliged to make a considerable detour, which entailed the crossing of the huge Koksel or

Sarguluk glacier descending northward from the great range we had surveyed before from the side of Lake Karakul. The lower portion of the defile was rendered altogether impassable by the summer floods of the glacier fed Yamanyar River. So I had to take to the difficult track known as Tokuz-Dawan, "the Nine Passes," and barely passable for laden animals, which crosses a series of steep transverse spurs descending from the little-known eastern slopes of the great snowy range behind Muztagh-Ata. Leaving the sub-surveyor and heavy baggage to follow by easier stages, I pushed on by rapid marches, and after a finishing march of some 50 miles from Tashmalik, on July 29 arrived at Kashgar.

There, under the hospitable roof of Mr. G. Macartney, C. I. E., the political representative of the Indian Government, the kindest reception awaited me. After fully two months of fatiguing and almost incessant travel in the mountains I felt the need of some bodily rest before I could set out again for Khotan, the proper goal of my explorations. But my four weeks' stay in Kashgar was mainly accounted for by other and more pressing considerations. In view of the wide extent of the area that was to be covered by my travels within a period practically limited to one autumn and winter, the careful organization of my caravan was a matter of much importance. In this respect the experienced advice of Mr. Macartney and the practical assistance of his establishment were of great value to me. It was essential to limit the baggage with a view to rapidity of movement, and at the same time to insure that all stores and equipment required during prolonged travels, and under widely varying conditions, should be kept readily available. I found that, including riding animals for myself and followers, 8 camels and 12 ponies would be needed for my caravan. The trouble taken about their selection was amply repaid by the result; for, notwithstanding the fatigues entailed by our subsequent travels, which covered an aggregate of over 3,000 miles, none of the animals I brought from Kashgar ever broke down. In the same way the number of followers was kept down to the indispensable minimum, the party including 2 camelmen, 2 pony attendants (one of whom had to act also as Chinese interpreter), a cook, and a personal servant for myself. Apart from the subsurveyor's Rajput cook, who had accompanied us from India, all the men came from Kashgar or Yarkand.

An important object of my stay at Kashgar was to familiarize the provincial Chinese Government with the purpose and character of my intended explorations. Mr. Macartney's efforts in this direction were entirely successful, owing mainly to the great personal influence and respect he enjoys among all Chinese dignitaries of the province. The result showed that from the Tao-tai, or provincial governor, downward, all Chinese officials I came in contact with were ready and anxious to render me whatever help lay in their power. I look back

to their invariable kindness and attention with all the more gratitude, as it was shown at a time when, as they knew well, the conflict with European powers was convulsing the Empire in the East.

Such imperfect explanations and illustrations as, with an interpreter's help, I could give of the historical connection of ancient Indian culture and Buddhist religion with Central Asia, probably helped to dispel any doubts and suspicions which might otherwise have been roused by the intended excavations, etc. In this respect I found my references to the Si-yu-ki, the records of Hiuen Tsiang's travels, singularly helpful. All educated Chinese officials seem to have read or heard legendary accounts of the famous Chinese pilgrim's visit to the Buddhist kingdoms of the "western countries." In my intercourse with them I never invoked in vain the memory of "the great monk of the Tang dynasty (Tang-Sen)," whose footsteps I was now endeavoring to trace in Turkestan, as I had done before in more than one part of India.

Busily engaged as I was during my stay at Kashgar with practical preparations, I managed also to survey a number of instructive ancient remains, chiefly ruins of Buddhist Stupas, in the vicinity, and to continue my studies of Turki. On September 11 I finally set out on the journey to Khotan. Choosing for the first portion of the march the track which crosses the region of moving sands around the popular shrine of Ordam-Padshah, I was able to fix the position of that curious pilgrimage place more accurately than is shown in existing maps. From Yarkand onward I followed the ordinary caravan route, which leads along the southern edge of the great desert, and mostly through barren, uninhabited wastes of sand or gravel, toward Khotan. For me it had a special historical interest; a variety of antiquarian and topographical observations which I was able to make proved beyond doubt that we were moving along the identical great thoroughfare by which in earlier times the trade from the Oxus and the Far West passed to Khotan and on to China.

It is impossible to refer here in detail to any of this evidence. But I may briefly mention at least the curious patches of ground frequently passed on the route beyond Guma, where the eroded loess is thickly strewn with fragments of coarse pottery, bricks, slag, and similar refuse, marking the sites of villages and hamlets long ago abandoned. Such débris areas, locally known as "tatis," are to be found in many places beyond the present limits of cultivation in the whole Khotan region; in some places they extend over whole square miles. They exhibit everywhere most striking evidence of the powerful erosive action of the winds and sand storms which sweep over the desert and its outskirts for long periods of the spring and summer. The above-named fragments rest on nothing but natural loess, either hard or more or less disintegrated. Having alone survived by the hardness and weight of their material, these fragments sink lower and lower as the

erosion of the ground beneath proceeds, while everything in the shape of mud walls, sun-burnt bricks, timber, etc., as used in the construction of Turkestan houses, has long ago decayed or been swept away.

On October 12 I reached Khotan town, the present capital of the territory which was to form the special field for my archæological explorations. I had entered the oasis on the preceding day with some feeling of emotion; for even before the discoveries that rewarded my labors there was much to suggest the important part played by this little kingdom in that most fascinating chapter of ancient history which witnessed the interchange of the cultures of India, China, and the classical West. I lost no time before commencing the local inquiries which were to guide me as to the sites particularly deserving exploration. Apprehensions about possible forgeries, which experience proved to have been fully justified, had prevented me from sending in advance information as to the object of my journey. I now found that some time would have to be allowed for the collection of specimens of antiquities from the various old sites which Khotan "treasure seekers" were in the habit of visiting. I was glad to utilize the interval for a geographical task which I knew to possess special interest.

That portion of the Kuen-luen Range which contains the headwaters of the Yurung-kash or Khotan River had never been properly surveyed, the only available information being contained in the sketch map of the route by which Mr. Johnson, in 1865, had made his way from Ladak down to Khotan. Colonel Trotter had already, in 1875, expressed the belief that the headwaters of the Yurung-kash were much farther to the east than shown in that map, and probably identical with a stream rising on the high plateau south of Polu. Captain Deasy, working from the side of Polu, in 1898, succeeded in reaching the sources of this stream at an elevation of close on 16,000 feet, but was prevented from following it downward. Thus the true course of the main feeder of the Yurung-kash, together with most of the orography of the surrounding region, still remained to be explored.

On October 17 I started with the lightest possible equipment for the mountains. Pan-Darin, the amban of Khotan, had, during the few days of my halt, done all that was needed to facilitate my arrangements for transport and supplies, and to assure me local assistance. Subsequent experience showed that I had found in this amiable and learned mandarin a true and reliable friend, thoroughly interested in my work, and ever ready to help me with all that was in his power. I feel convinced that without his active cooperation, and subsequently that of his Keriya colleague, neither the tour through the mountains nor the explorations in the desert could have been accomplished.

The valley of the Yurung-kash becomes impassable within one march of its debouchure. There, near the small villages of Jamada and Kumat, the precious jade is dug, from which the river takes it name—

"white jade." Hence the route to Karanghu-tagh, the southernmost inhabited place, leads over a series of more or less parallel ranges that separate side valleys draining from the east. These outer ranges, rising in a succession of plateaus fissured by deep winding ravines, exhibit in a most striking form the results of that extreme disintegration which is the characteristic feature of the whole mountain system. Nothing but loose earth, gravel, or conglomerate in the last stage of decomposition is to be seen on the surface of the hillsides; while their high elevation and the dryness of the climate prevent the growth of any but the scantiest vegetation in rare patches of low, tough grass. The effects of the dust haze which rises so constantly over the desert plains were still sufficiently marked to prevent any distant view being obtained from the Ulugh Dawan, by which we crossed the Tikelik Range at an elevation of about 12,000 feet. But from the next range, between the valleys of Buya and Pisha, a very extensive panorama opened out before us.

In a grand mountain mass raising its glacier-crowned head in solitary splendor to the southeast, it was impossible to mistake the "Kuen-luen peak, No. 5," already triangulated from the Ladak side (pl. II). Behind this great mountain, for which the tables supplied by the survey department indicated a height of 23,890 feet, to the south and southeast there was to be seen a magnificent line of high snowy peaks marking the watershed toward the westernmost portion of the Aksai-chin plateau of Tibet. It soon became clear that the Yurung-kash has cut its way between the main range and the great mass of "K5," or Muztagh ("the ice mountain," κατ' ἐξοχὴν, as it is called by the few Taghliks of these valleys). Its course is indicated by a gap between the stupendous spurs which descend from Muztagh, and from the almost equally high peaks on the watershed range, and could, in the remarkably clear atmosphere that favored us, be made out for a considerable distance to the southeast. It was found to run exactly in the direction where Captain Deasy had traced the real source of the river. In other respects, too, the orographical features actually before us differed strikingly from those which the above-mentioned sketch map had led me to expect.

The next outer range, which was crossed at an elevation of close on 14,000 feet, offered a still better view of this magnificent panorama. But vainly I searched the crest line for other peaks which could be identified with points already triangulated from the Ladak side, and which would thus secure to us the eagerly sought connection with the Indian trigonometrical system. The descent which followed, of some 6,000 feet, to the deep rock-bound gorge of the Yurung-kash, was by its steepness and ruggedness an experience long to be remembered, especially as night overtook us. The track was almost impracticable

for our baggage ponies. Fortunately it was possible to replace them by yaks at Karanghu-tagh, a small settlement of herdsmen which, owing to its inaccessibility, is also used as a penal station for select malefactors from Khotan. "Karanghu-tagh" literally means "mountain of blinding darkness"—a fitting enough name for this terribly bleak place of banishment. The Kash River, on which it lies, is fed by a series of great glaciers on the main range to the south, and joins the Yurung-kash a few miles below the hamlet.

Leaving the ponies and whatever of baggage could be spared at Karanghu-tagh, I endeavored to follow up the gorge of the Yurung-kash as far as possible toward the head of the river. The hillmen knew of no track beyond a point known as "Issik-bulak," from its hot-spring. There the river, unfordable even late in the autumn, fills completely the narrow passage it has cut round the mighty southern buttresses of "Kuen-luen No. 5," and progress becomes impossible, even for yaks. Accompanied by Ram Singh and a couple of Taghliks, I penetrated, on October 27, a few miles farther into the gorge, climbing with difficulty along the precipitous cliffs which face the frowning ridges on the south. But no track could be discovered practicable for load-carrying men, and ultimately I had to turn back. It was impossible for me to wait for the chance of the river getting completely frozen. Even then I doubt whether a practicable passage could be secured, considering the rigors of the winter and the masses of fallen rock likely to be encountered. It is from the high but comparatively open ground near the sources far away to the southeast that the uppermost portion of the river course will have finally to be explored.

From Karanghu-tagh we proceeded to the northwest by a difficult route, which forms the only connection of the valley with the outer world besides that we had come by. It required a good deal of negotiation and "demiofficial" pressure before the surly hillmen of Karanghu-tagh would supply guides and yaks for it. The inhospitable mountain tract into which it took us had so far remained wholly unexplored.

Over a succession of high transverse ranges we crossed into the valleys of Nissa and Chash. By camping close to the passes we managed to climb to some excellent survey stations, particularly on the Brinjak ridge, some 15,300 feet above the sea. The views I obtained there will show, better than any description could, the weird grandeur of this mountain scenery. Below a glacier-clad crest line, of an approximate height of 20,000 feet, there rise in all directions fantastically serrated ridges, with deep gorges between them, like the waves of an angry sea. Exceptionally clear weather favored us; but the increasing cold and the exposure inevitable on such elevated ground made survey work, especially with the phototheodolite, very trying. (Pl. III).

Beyond the Yagan-Dawan Pass, by which I crossed into the drainage area of the Kara-kash ("black jade") River, I had ample opportunity to observe the extraordinary results produced by erosion on mountain formations subject to excessive disintegration (pl. III). It appeared to me that only the erosive action of water could have produced that perfect maze of deep-cut arid gorges through which we had to wind our way. Yet in this very region the fall of rain and snow is now very scanty, and the consequent absence of water is a serious obstacle for the traveler. Luckily, we could overcome it by the transport of ice.

I had almost despaired of connecting our survey work with the Indian triangulation, when unexpectedly the last range we had to cross toward the plains revealed a view more extensive than any before. Among the many high snowy peaks visible southward, and also beyond the upper Kara-kash River, two more triangulated points, besides "Kuen-luen No. 5," could be identified with certainty. It thus became possible to determine our position on the Ulughat-Dawan, close on 10,000 feet above the sea, by theodolite and to measure angles to all prominent heights of the ranges within view. To the north there extended, boundless like the sea, the vast plain of the desert. The light dust haze covering it looked beautiful as it reflected the brilliant moonlight of that first night I spent on the pass waiting for the arrival of water. The dinner for which it was needed, did not get ready till 2 a. m. I knew that a wind raising the haze would effectively stop further survey work. So I hurried to reach another high ridge farther east, with an equally extensive view, that would allow us to complete the triangulation. It was successfully climbed after a great detour that cost us two days, and just in time. As the work was approaching completion, a strong wind sweeping over the desert carried up a thick dust haze, and for weeks effaced all distant views. Some prominent peaks in the outer range of hills, which are visible from Khotan town when the atmosphere is clear, have been fixed by our work. With the help of these points it will be possible to connect Khotan with the Indian trigonometrical system, and finally to verify its longitude. But such occasions of dust-clear weather are rare, and of the only one which occurred during my subsequent short stay in Khotan, in April, full advantage could not be taken by myself. Thus this task is still left to a future traveler, who will be able to afford time for patiently awaiting his opportunity at Khotan.

By the middle of November I had returned to Khotan, where, after our rough and rapid marches through the mountains, I was glad to allow my men and animals a well-earned short rest before starting once more for the winter's work in the desert. I myself was busy at work with the examination of the antiquities which the prospecting parties, sent out a month earlier, had brought back from various sites

in the desert. I also made a series of excursions for the purpose of a close survey of the old localities within the Khotan oasis itself. This enabled me satisfactorily to settle numerous questions bearing on its ancient topography, and in particular to locate almost all the sacred Buddhist shrines which are described to us by the early Chinese pilgrims. Their positions were invariably found to be occupied now by Muhammadan Ziarats, or Saints' tombs, which form the object of popular pilgrimage. Local worship can thus be shown to have outlived the great change in religion consequent on the Muhammadan conquest. Its tenacity has indeed proved quite as useful for the study of the ancient topography of Khotan as it had proved to me before in Kashmir and other parts of India.

I must restrict myself here to a few remarks only concerning the most interesting of those old localities—the site of the ancient capital. Its débris layers, which have furnished by far the greatest portion of the Khotan antiquities, such as terra cottas, seals, coins, etc., acquired by former travelers, lie buried deep below the fields of the little village of Yotkan, some 7 miles to the west of the present town. Gold-washing operations, originating from an accidental discovery of gold some thirty-seven years ago, have gradually led there to the excavation of an area over half a mile square. The careful examination of the banks thus laid bare showed me that the "culture strata," as I should call them, of Yotkan are composed of the rubbish that gradually accumulated during the centuries while the site continued to be occupied by houses, from about the commencement of our era until after the advent of Islam (in the eleventh century of our era). These "culture strata," themselves 5 to 14 feet thick at various points, are covered by a layer of pure soil from 9 to 20 feet in thickness. This layer, which shows no sign of stratification, is manifestly due to silt deposit, the necessary result of intensive and long-continued irrigation such as prevails all over the oasis. Owing to the disintegrated condition of the soil, all the water that is brought down from the mountains by the Yurung-kash and Kara-kash rivers, and subsequently distributed by innumerable irrigation channels, carries an excessive quantity of sediment. The silt thus deposited over all cultivated areas is amply sufficient to account for the gradual burying of the rubbish layers of the ancient capital and for other curious observations I have made as to the gradual raising of the ground level throughout the oasis. All antiquarian and physical evidence combines to oppose the assumption of a great flood or similar catastrophe, such as some earlier European visitors of the site have suggested.

Among the ancient sites in the Taklamakan Desert which are frequented by Khotan "treasure seekers," and which the prospecting parties sent out by me had visited, none seemed to offer better opportunities for systematic excavations than the one known to them as

FIG. 5.—GLACIERS AT HEAD OF KASH RIVER, SEEN FROM BRINJAK RIDGE.

FIG. 6.—ERODED RANGES TO SOUTHEAST OF YAGAN-DAWAN.

FIG. 7.—STUCCO SCULPTURES AND FRESCOES IN BUDDHIST TEMPLE CELLA EXCAVATED AT DANDAN-UILIK.

FIG. 8.—ROOM OF ANCIENT DWELLINGS (FIRST FIND PLACE OF INSCRIBED TABLETS), NIYA RIVER SITE, AFTER EXCAVATION.

Dandan-Uilik. Turdi, an old and, as experience showed, reliable member of that fraternity, had brought me from there some interesting relics, including fragments of Buddhist sculptures, an inscribed piece of fresco, and a small but undoubtedly genuine scrap of paper with ancient Indian Brahmi characters. Further inquiries made it certain that Dandan-Uilik was identical with the ruined site which Dr. Sven Hedin had seen on his march to the Keriya Darya, and which in the narrative of his travels is spoken of as "the ancient city Taklamakan."

After hurriedly completing in Khotan the preparations for our winter campaign, I started on December 7 for Tawakkel, a small oasis on the outskirts of the forest belt which accompanies the Yurung-kash on its course through the desert. Thanks to the stringent orders issued by Pan-Darin, the kindly amban of Khotan, I speedily secured there the 30 laborers I wished to take with me for purposes of excavation, as well as a four-weeks' food supply. Owing to the reluctance of the village cultivators to venture far into the desert, it would otherwise have been difficult to obtain sufficient labor, especially in view of the rigors of the winter. The ponies, for which the desert offered neither sufficient water nor food, were sent back to Khotan, while we set out on foot, the heavily-laden camels carrying the food supplies, together with the indispensable baggage. Marching in the drift sand was slow work, though the dunes amidst which we passed as soon as we had left the east bank of the river nowhere rose above 15 feet. Within five days Turdi had safely guided us through the sandy waste to the area where the trunks of dead poplars, rising shriveled and gaunt from between low dunes, indicated the vicinity of ancient cultivation. On the following day (December 18) I had my camp pitched in the middle of the ruins I was in search of.

I soon found that the structural remains of the site consisted of isolated groups of small houses scattered over an area about 1½ miles from north to south and three-quarters of a mile broad. The walls, constructed throughout of a wooden framework covered with plaster, were either broken down within a few feet from the ground, if exposed, or, where covered by low dunes, could be made out by the wooden posts of the framework sticking out from the sand. The structures left more or less exposed had already been searched by native "treasure seekers." Their operations repeated in successive seasons had, together with the erosive action of the wind, caused great destruction among these ruins. But the scanty remains left on some walls of frescoes representing Buddhas, or Bodhisattvas, showed at once plainly that the ruins belonged to the Buddhist period, and that some of them must have served as Buddhist places of worship.

Luckily the native "treasure seekers" are prevented by the difficulty of carrying sufficient supplies from stopping longer than a few

days, hence they had never been able to attack the ruins more deeply covered by the sand. Thus, when I commenced with my little force of laborers the systematic excavation of structures half buried by low dunes, most interesting archæological results soon began to reward me. From the cellas of little Buddhist shrines there came to light in large numbers stucco images and relievos, frescoes and painted wooden tablets, all showing representations of saints and legends of sacred Buddhist lore (pl. IV). In style and technical treatment they exhibit a close resemblance to that period of ancient Indian art which is best known to us from the latter Ajanta cave paintings. Wherever protected by the dry desert sand, the colors have survived in remarkable freshness. Here, then, were rising from their tomb long-lost relics of that Indian art which had found a second home in Buddhist Central Asia before spreading farther into the Far East.

Great was my joy when, on excavating what must have been the ground-floor room of a small monastic dwelling place, the men came upon the first leaves of paper manuscripts. Carefully extracted with my own hands and cleared, they proved to contain portions of a Buddhist canonical text in Sanskrit. Judging from the palæographic character of the writing, these and subsequent finds of fragmentary Sanskrit manuscripts from Dandan-Uilik ruins may approximately be assigned to the sixth or seventh century of our era. In addition to such texts in the classical language of India, the literary discoveries of this site include a considerable number of manuscript folia and of detached documents on paper, written in Indian Brahmi characters, but in a non-Indian language. Taking into account that the same strange language appears in inscriptions affixed to some frescoes, it seems probable that we have here records of the indigenous tongue actually spoken by the Khotan people of that period. Only the close study of all these documents—a task which may take years—is likely to lead to a decipherment, and thus to a solution of this interesting question.

In the meantime it is fortunate indeed that the discovery of Chinese paper documents in other small monastic dwellings permits us to determine with accuracy the period when the settlement represented by the settlement of Dandan-Uilik was finally abandoned. Among the neatly folded small paper rolls containing letters, records of loans, petitions, and similar matter, there are three at least which already, on preliminary examination at Kashgar, proved to be dated with precision, the Chinese years indicated corresponding to the years 778, 782, 787 of our era. There are good reasons for assuming that these petty records do not precede by any great length of time the date when the dwellings were abandoned. We thus obtained the end of the eighth century as the approximate chronological limit for the existence of Dandan-Uilik as an inhabited locality. This dating is

entirely supported by the evidence of the numerous old Chinese coins I found at the site, the latest bearing the symbols of the dynastic period which corresponds to the years 713–741 A. D.

The three weeks I spent in continuous excavations, from the early morning until daylight failed us, enabled me to explore all ruins traceable under the sand. It was a happy time for me personally, though the physical conditions were trying. The severe winter of the desert had already set in when I started from Khotan. During my stay at Dandan-Uilik the temperature at night usually went down to a minimum of about 10° F. below zero. In the daytime it never rose above freezing point in the shade. The weather was cloudy, but luckily there was very little wind. Its absence is an essential condition for all prolonged work in the desert. The dead trees of the little orchards which once surrounded most of the scattered groups of shrines and dwellings supplied fuel in plenty. Yet the men suffered from the exposure as well as from the badness of the water, the only available supply coming from a brackish well they had succeeded in digging in a depression of the ground over a mile from the main ruins. My own little tent, brought from India, though provided with an extra serge lining, was a bitterly cold abode at night. When the temperature had once gone to about 6° below freezing point, writing or reading became impossible, and I had to take to my bed, however anxious I might have been to study the manuscript finds of the day, etc. But, from long experience, life in a tent seems the one most congenial to me, and, with such fascinating work to occupy me, the four and a half months spent in the desolation of the desert were indeed an enjoyable time.

During my stay at Dandan-Uilik, Ram Singh had again joined me from the direction of the Keriya River. I had dispatched him a month earlier on an independent survey of the high range which extends between "Kuen-luen No. 5" and the mountains eastward where connection could be obtained with Captain Deasy's work about Polu. On comparing my own plane-table fixing for Dandan-Uilik with his, a gratifying surprise awaited me. Notwithstanding that we had brought our survey from entirely different directions and over great distances of such deceptive ground as sandy planes and dunes, I found that Ram Singh's position differed from my own by only about a mile in latitude and a half mile in longitude.

My detailed survey of the Dandan-Uilik site, together with other observations of a semitopographical, semiantiquarian nature which gradually accumulated during my explorations at this and other sites, make it very probable that the lands of Dandan-Uilik were irrigated from an extension of the canals which had, down to an even later date, brought the water of the streams of Chira and Gulakhma to the desert area due south of the ruins. I must reserve for another occasion a

discussion of the archæological evidence as to the causes which led to the abandonment of this advanced settlement. There is every reason to believe that this abandonment was a gradual one, and in no way concconnected with any sudden physical catastrophe. The Sodom and Gomorrha legends heard all over Turkestan about "old towns" suddenly submerged under the sand dunes are more ancient than the ruins of Dandan-Uilik themselves and interesting as folklore. But where we have plain historical and antiquarian evidence to the contrary, scientific inquiry can have no concern with them.

On January 6 I dismissed my Tawakkel laborers who had worked so valiantly, and after a three-days' march over truly forbidding ground, struck the Keriya Darya. The successive ridges of sand, rising to heights of about 200 feet, were the most formidable I ever crossed. A four-days' march along the hard-frozen river brought us to the oasis and town of Keriya, where Khon-Daloi, the amban, accorded me the heartiest welcome. There I first heard of the existence of "an old town"—kone shahr, as all ruins are popularly called in Turkestan in the desert north of the well-known pilgrimage place of Imam-Jafar-Sadik. The information was very scanty, and the distance great. But certain indications pointed to a site of special interest; so I decided to set out for it after a few days' halt needed to rest my followers.

At Niya, which is the easternmost permanently inhabited place of the district, just as in the days of Hiuen Tsiang, who notices it under the name of Ni-jang, I received most encouraging proof that I was on the way to a site far older and hence more important than any I had examined so far. Owing to its great distance, the Khotan "treasure seekers" knew, luckily, nothing of it. An adventurous young villager from Niya was the only man who in recent years had visited the ruins. From one of the ruined houses he had picked up two small wooden tablets. When they were brought to me I noticed at once that the writing they contained was in the ancient Indian script known as Kharoshthi, and of a type that chronologically belongs to the first and second centuries of our era. I hid my delight as well as I could, and pushed on still more rapidly, after securing a sufficient number of laborers and the needful supplies for prolonged excavations. After a three days' march through the belt of thick jungle which lines the winding course of the Niya River through the desert, the curious shrine of Imam Jafar Sadik was reached. There the river finally loses itself in the sands, and as water can not be obtained by digging, we had to depend for our further progress on what could be carried along from that locality. Fortunately the intense cold still prevailing through this and the following month (on January 26 I registered a minimum of 12° F. below zero) permitted its convenient and regular transport in the form of ice.

After a march of about 30 miles through the desert northward, I arrived on the evening of January 27 at the southern edge of the wide area over which are scattered the ruins I was in search of. The subsequent explorations showed that it extends for over 11 miles from north to south, with a maximum breadth of about $4\frac{1}{2}$ miles.

Pitching my camp near a small stupa half buried in the sand, I proceeded next morning to the ruined house where Ibrahim, the young Niya villager already mentioned, had unearthed his inscribed tablets. He declared he had left more in situ. It was a moment of cheerful excitement when I approached the timber débris, rising like the remains of a wreck from the eroded ground around it. On the sandy slope I found at once some tablets actually exposed, and many more scattered about under a slight layer of drift sand within the small room where Ibrahim had originally unearthed them (pl. IV). The house which contained it had, like the rest of the buildings at this site, been constructed of a wooden framework of massive beams and posts. Between the latter rose the walls of hard plaster, strengthened internally by thick mattings of rushes. These walls had completely decayed where not actually covered by sand, but the posts, now blanched and splintered, still rise high above the surface. In the building first explored, the sand, which during former centuries must have protected it, had largely drifted away. The remarkable state of preservation in which many of the inscribed tablets were found was hence all the more surprising. Over 100 were cleared from the little room already mentioned, and the excavation of a large room of the same building, on the day following, more than doubled that number. Unfortunately the protecting layer of sand was here only about 2 feet deep, and in consequence all materials not lying quite flat on the floor had decayed completely.

The present condition of this ruin, which originally appears to have been used as a monastic building, illustrates strikingly the destructive effect of erosion on this and other structures of the site. The actual remains of the building occupy a small plateau raised now 12 to 15 feet above the immediately surrounding ground. The lower level of the latter is the unmistakable result of erosion. While the strip of ground actually protected by the débris of this and similar structures retains the original level, the open surface near by, consisting of mere loess, has been gradually lowered by the action of the wind. The drift sand carried along this portion of the desert is not sufficient at present to fill the depression thus created. From the geological point of view, not less than from the archæological, it would be interesting to study the exact conditions under which the power of the desert winds asserts itself in its two main lines of action—erosion and the movement of drift sand. But I am convinced that it will take years of minute and systematic observation before any safe conclusions can

be arrived at as to the rate at which the work of these forces proceeds in various parts of the Taklamakan. And even then there will be little to guide us as to the corresponding conditions prevailing during earlier historical periods.

While most of the buildings of this important site had suffered from erosion, there were others where parts at least were still buried under deep sand (pl. v). From some of these my excavations brought to light many very interesting objects illustrating the industrial arts of the period. The articles of ornamental wood carving, which include elaborately worked chairs, small architraves and other achitectural pieces, etc., show decorative motives familiar to us from the relievo sculptures of the ruined Buddhist monasteries on the northwest frontier of India, the ancient Gandhara. The date thus indicated fully agrees with the chronological evidence of the Kharoshthi writing on the wooden tablets, apparently memoranda and lists, found scattered in various rooms of the same dwellings. Broken pieces of arms, household implements, a musical instrument and similar objects of domestic use, all of wood, help vividly to bring before our eyes the conditions of everyday life of this distant region in the first centuries of our era.

It was difficult for me to realize fully that so many centuries had passed since these dwellings were deserted while I traced the plan and arrangement of the orchards and gardens once surrounding them. Rows of fallen poplars, some 50 feet in length, half covered by the sand, showed the position of avenues, such as are planted to this day everywhere along the roads and canals of Turkestan oases. The rush fences used then, as now, for the inclosures of gardens could be seen sticking out from the sand. A little digging along them often revealed small heaps of dry leaves that must have accumulated there while the trees, now reduced to blanched and withered trunks, were still thriving. Among these my diggers had no difficulty in distinguishing various fruit trees, such as the peach, plum, apricot, mulberry, etc., with the wood of which they are familiar from their own homes.

The character and conditions of the articles found within the houses plainly showed that they had been cleared by their last inhabitants, or soon after their departure, of everything that possessed value. Luckily, there were left behind the rubbish heaps to reward me with finds of the greatest antiquarian interest. The richest mine of this sort was struck in a small and much-decayed building, one room of which proved to contain a consolidated mass of refuse, lying fully 4 feet above the original floor. Among the layers of broken pottery, rags of felt and of woven fabrics, pieces of leather and other rubbish, I discovered there over two hundred documents on wood, of all shapes and sizes. Besides tablets with the Indian Kharoshthi writing, which form the great majority, there came to light numerous narrow pieces of wood bearing Chinese characters, and two dozen Kharoshthi docu-

FIG. 9.—SAND-BURIED ANCIENT HOUSE, NIYA RIVER SITE, BEFORE EXCAVATION.

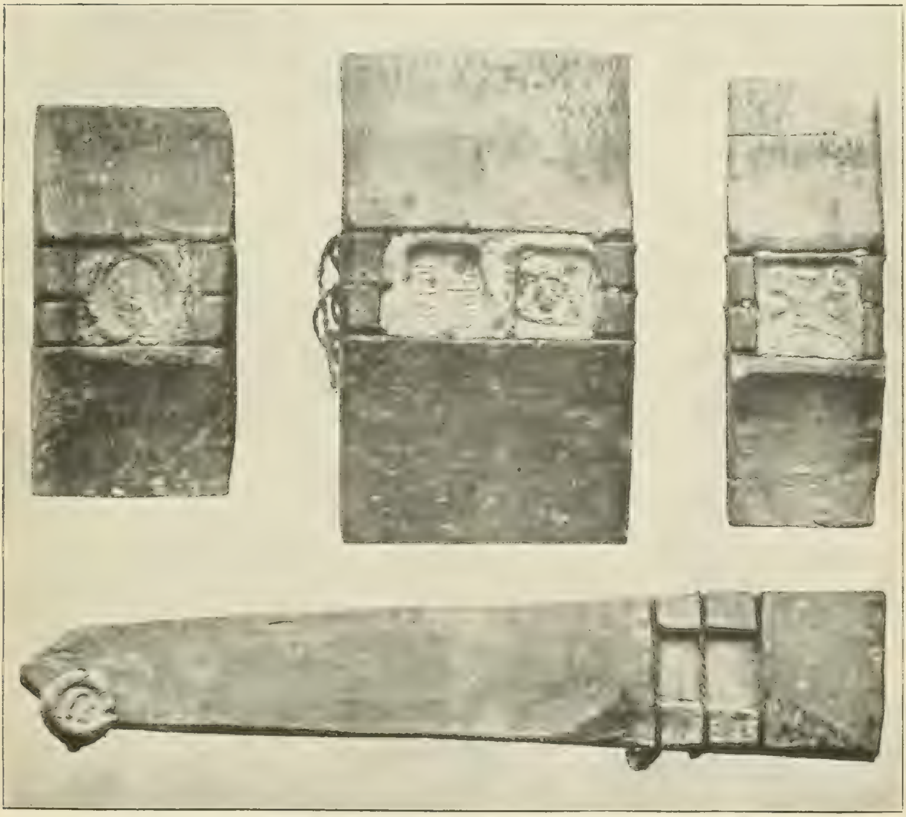


FIG. 10.—COVERING TABLETS OF ANCIENT KHAROSHTHI DOCUMENTS ON WOOD, WITH CLAY SEALS ($\frac{2}{3}$).

FIG. 11.—RELIEVOS AT OUTER SOUTHEAST CORNER OF QUADRANGLE OF RAWAK STUPA COURT.

FIG. 12.—COLOSSAL STATUES ON INNER SOUTH WALL OF RAWAK STUPA COURT.

ments on leather—a material one could hardly expect to find among a Buddhist population with an Indian civilization.

Many of the Kharoshthi tablets unearthed are in excellent preservation, and still retain the original clay seals and strings with which they were fastened (pl. v). We are thus able to study exactly the technicalities connected with the use of wood as a writing material. This is not the place to discuss such details, but I may mention at least that each document intended as a letter or record of some importance, whether wedge-shaped or oblong, is provided with a carefully fitted covering piece or envelope bearing the address or "docket" entry. An ingeniously designed system of fastening with a string and a neatly inserted clay seal, prevented unauthorized inspection of the contents.

The remarkable series of clay seals discovered on these tablets is of exceptional interest, because it furnishes most convincing evidence of the influence which classical western art has exercised even in distant Khotan. A frequently recurring seal, probably that of an official, shows the figure of Pallas Athene, with shield and ægis, treated in archaic fashion. Another fine seal is that of a well-modeled naked figure of pure classical outline, perhaps a seated Eros. On others, again, appear portrait heads showing classical modeling, though barbarian features, etc. We know well how classical art had established its influence in Bactria and on the northwest frontier of India. But there was little to prepare us for such tangible proofs of the fact that it had penetrated so much farther to the east, to halfway between western Europe and Peking. I may note here, as an interesting discovery made while these pages are passing through the press, that Professor Karabacek has traced the remains of a Greek legend, apparently a magic formula, impressed on the edge of one of the clay seals, containing in its center the figure of Athene Promachos.

From the contents of the documents themselves we may confidently expect much fresh light upon a chapter of Central Asian history and civilization which until now has seemed almost entirely lost. Owing to the great number of the texts, the cursive character of the script, and peculiar difficulties connected with the nature of the records, their complete decipherment will require much time and labor. But it is already certain that, as I recognized in the course of my first examination on the spot, the language of the documents is an early form of Indian Prakrit, with a large admixture of Sanskrit terms. It is highly probable that most of them contain official orders, such as safe conducts, correspondence, etc., as well as private memoranda and records. Religious texts, prayers, etc., may be suspected in some of the long tablets found in what seem to be shrines or monasteries. Many of the documents bear exact dates, in which the years are indicated with reference to the reigns of named rulers. These will enable us probably to restore a portion of the historical chronology of this region.

But whatever revelations of interesting detail may be in store for us, one important historical fact stands out clearly already. The use of an Indian language in the vast majority of these documents, when considered together with the secular character of most of them, strikingly confirms the old local tradition recorded by Hiuen Tsiang that the territory of Khotan was conquered and colonized about two centuries before our era by Indian immigrants from the northwestern Punjab. It is a significant fact the Kharoshthi script used in our tablets was peculiar to the very region of ancient Taxila, which the above tradition names as the original home of those immigrants. It is strange, indeed, that the ruined dwellings of a settlement far away in the barbarian north, overrun by what Hindu mythology knew as the "great sand ocean," should have revealed to us, after nearly two thousand years, the oldest written documents (as distinguished from inscriptions), and of a type of which ancient specimens have never come to light as yet in India proper. It is equally strange, and yet easily explained by the historical connection of Khotan with China, that we should find buried along with them what are likely to prove the oldest written Chinese records actually extant.

There is ample evidence to show that this remarkable site must have been deserted already within the first few centuries of our era. Apart from the Kharoshthi writing of the tablets and leather documents, which agrees closely in its palæographic features with the Kharoshthi inscriptions of the Kushana kings of the first and second centuries, there is the eloquent testimony of the coins. The very numerous finds, extending over the whole area, which were made during my stay include only copper pieces of the Chinese Han dynasty, whose reign came to a close in A. D. 220. The use of wood as the only writing material, apart from leather, is also a proof of great antiquity. The use of paper for writing purposes is attested in Chinese-Turkestan from at least the fourth century A. D. onwards; yet among all the ruined houses and ancient rubbish heaps not the smallest scrap of paper was discovered.

After three weeks of almost incessant excavation work I left this fascinating site which had yielded such rich antiquarian spoil in order to visit, farther to the east, ruins I had heard of at Niya. A march of about 100 miles through the desert, due east of Imam Jafar, brought us to where the Endere stream is lost in the sands. After a day's march farther to the southeast I found a ruined Stupa, and at some distance from it a small circular fort filled with sand-buried buildings.

My excavations at what proved to be a Buddhist temple, situated in the very center, brought to light some interesting stucco sculptures, and, besides, a considerable quantity of manuscript leaves on paper. They belong to a variety of texts in Sanskrit, Tibetan, and the unknown language written in Indian characters, already referred to in

connection with Dandan-Uilik. The Tibetan leaves, containing, as Mr. Barnett of the British Museum has ascertained, portions of a translation of the Salisthambasutra, a Buddhist canonical text, undoubtedly are the oldest written remains of that language as yet discovered. It was curious to note how the folia which originally belonged to a fairly large manuscript had been cut up and separately deposited, manifestly as votive offerings, at the pedestals of various images. A pious visitor of the shrine had evidently endeavored to propitiate with his text as many divinities as possible. To other curious discoveries made there, such as Tibetan and Chinese Sgraffitti, small votive offerings of elaborately woven fabrics in silk and cotton, etc., I can only allude here. But as a point of chronological importance it may be mentioned at least that in one of the Chinese Sgraffitti, of which I brought away photographs, Professor Douglas has since read a date corresponding to A. D. 790.

The proofs of Tibetan occupation showed me that I had reached at Endere the easternmost limits of the territory with the archæological exploration of which I was concerned. So, on February 26 I could turn back with a good conscience toward the west, where several sites yet remained to be examined. The journey to Keriya, a distance of over 180 miles, was covered in seven forced marches. The energetic assistance of Khon-Daloi, the Amban, who had followed my movements with the friendliest care and interest, allowed me to set out at once with fresh laborers, transport, and supplies for Karadong, the ancient site in the desert, some 150 miles north of Keriya, which Dr. Sven Hedin had first visited.

This so-called "ancient city" proved to contain little more than the ruins of a roughly built quadrangular structure, which probably had served as a fortified sarai, or post, on the ancient route leading along the Keriya Darya toward Kuchar in the north. My excavations at this desolate spot were carried on under considerable difficulties. The height of the dunes which covered the interior of the great quadrangle was considerable, and daily we were visited by sand storms of varying degrees of violence. The finds, which were scanty, as I had expected, curiously enough included small quantities of remarkably well-preserved cereals, such as wheat, rice, pulse, etc., found embedded in the floor of what evidently was an ancient guard room.

A series of hurried marches brought me back once more to the vicinity of the present inhabited area. Various antiquarian and topographical considerations made me look out in the desert north of the oasis of Gulakhma for the remains of the town of Pi-mo, which Hiuen Tsiang visited on his way from Khotan to Niya, and which is probably mentioned also by Marco Polo under the name of Pein. After a search, rendered difficult by the insufficiency of guides and the want of water, I succeeded in tracing it in an extensive débris-covered site known as

"Uzun-Tati" ("the distant Tati"), in the desert north of the oasis of Gulakhma. Far-advanced erosion and the operations of treasure seekers from the neighboring villages have left little of structural remains, but the usual débris of broken pottery, glass, china, etc., was plentiful.

A close inspection of the conditions under which cultivation is carried on in this vicinity, along the edge of the desert, was very instructive from the point of view of historical topography. I found that, owing to a difficulty of conducting the irrigation water sufficiently far, some villages of this oasis had, within the memory of living men, been shifted as much as 6 to 8 miles farther to the south. The crumbling ruins of the old village homesteads, stripped of all that could be of use, are still to be seen. Over miles of ground, which the desert sand is slowly overrunning, the lines of empty canals, embanked fields, etc., can be made out with ease. It was the best illustration I could have of the process which many centuries ago must have followed the abandonment of ancient localities like the Niya River site and Dandan-Uilik.

Increasing heat by day and recurring dust storms warned me that the season was close at hand when work in the desert would become impossible. So, as soon as I had returned to the outskirts of Khotan on April 5, I set out for the ancient sites which still remained to be examined in the desert northeast of the oasis. There a discovery of unexpected importance awaited me; for when, after examining Aksipil and other débris areas, I arrived at Rawak, of which Turdi, my honest old guide, had spoken merely as "an old house," I found before me a large Stupa, forming, with its inclosing quadrangle, by far the most imposing of all extant ruins of this region. The excavations I at once commenced along the massive walls of the great stupa court revealed a remarkable series of colossal statues in stucco, representing Buddhas or Bodhisattvas, with many smaller relievos between them (pl. VI). The walls were further decorated with elaborate plaques forming halos, as well as with fresco paintings. The whole of the relievo work had originally been painted.

The careful excavation of this wealth of sculpture was a difficult matter. The interior framework of wood, which once supported the masses of stucco, had rotted away, and, deprived of this support, the heavy images threatened to collapse when the protecting sand was being removed (pl. VI). The risk was considerably increased by the Burans, which were blowing with more or less violence during the whole of my stay. Extreme care was needed in clearing the statues, and their lower portions had to be covered up again as soon as they had been photographed. An attempt to remove the larger sculptures was quite impracticable owing to the extremely friable condition of the stucco and the difficulties of transport. But of the smaller ones and of pieces

found already detached I succeeded in bringing away a considerable number without mishap.

The Rawak relievos show in style and most details of execution the closest affinity with the so-called Græco-Buddhist sculptures of the ruined monasteries and shrines on the northwest frontier of India. This makes their close study, with the help of the numerous photographs I secured, a matter of great historical and artistic interest. Though no epigraphic or manuscript remains have come to light, the evidence of the numerous coins I found, deposited as votive offerings, goes far to prove that the sculptures of the Rawak Stupa belong approximately to the same period as the ruins of the "Niya River site."

The daily sand storms, together with the increasing heat and glare, had made the work of excavation at Rawak trying to the men as well as myself. So I was glad when the completion of this task permitted us to withdraw from the desert. On my return to Khotan I was busy with arranging my collections of archæological finds and repacking them for their long journey to London. While thus engaged I succeeded in clearing up the last doubts as to the real nature of the strange manuscripts and "block prints" "in unknown characters" which had, during recent years, been purchased from Khotan in such remarkable numbers, and which had found their way not only to Calcutta but also to great public collections in London, Paris, and St. Petersburg. The grave suspicions which my previous inquiries had led me to entertain as to the genuineness of these supposed "finds" had gradually been strengthened almost to certainty by the explorations of the winter. Ample and varied as the manuscript materials had been which rewarded my excavations, I had utterly failed to trace the smallest scrap of writing in "unknown characters." The actual conditions of the sites explored also entirely differed from the conditions under which those queer manuscripts and prints were alleged to have been discovered. There was good reason to believe that Islam Akhun, a native of Khotan, from whom most of those purchases had been made during the years 1895–1898, was directly concerned in the forgeries.

After my return to Khotan I expressed to Pan-Darin a wish for a personal examination of this interesting individual. Some days later he was duly produced from a village of the Keriya district, where he had recently been practicing as a "medicine man." Islam Akhun's examination proved a lengthy affair. He readily acknowledged his guilt in various recent frauds (including one practiced on Captain Deasy), for which he had received due punishment from local Chinese justice. But in the matter of the "old books" he at first protested complete innocence. His defense, however, collapsed in the course of a

prolonged cross-examination, and ultimately he made a full confession. The detailed explanations he then furnished of the circumstances which had first led to the conception of these forgeries, and of the methods and materials employed in their manufacture, were interesting enough, and proved, on comparison with the record which had been kept at Kashgar of the purchases, remarkably accurate. Notwithstanding the ingenuity displayed in starting these forgeries, Islam Akhun and his factory "hands" had never succeeded in producing a text exhibiting consecutively the characters of any known script. Also, in other material respects, it is easy now, in the light of the experience gained through my explorations, to distinguish between his fabrications and genuine ancient manuscripts. There is, therefore, little fear that the forgeries of this clever scoundrel will ever cause deception thereafter.

On April 28 I bade farewell to Khotan town, and May 12 saw me once more at Kashgar, under the hospitable roof of my friend Mr. Macartney, the British representative. Since my departure, eight months earlier, Mr. Macartney had lost no opportunity to facilitate my labors. The assistance of the Chinese officials, which was essential for the success of my explorations, had been secured mainly through his influence and unfailing care. For all the help thus accorded to me I wish to express here my feelings of sincere gratitude. * * *

PORTION OF CHINESE TURKESTAN. FROM STEIN'S LARGE COLORED MAP.

FROM THE SOMALI COAST THROUGH SOUTHERN ETHIOPIA TO THE SUDAN.[a]

By Oscar Neumann.

In the spring of 1899 Baron Carlo von Erlanger asked me to join an expedition to Somaliland which he intended to undertake for the sake of sport and ornithological research. I agreed on condition that the journey should not be confined to Somaliland, but should also extend to the countries of southern Ethiopia. The preparations took nearly half a year. Meanwhile the revolt of the "Mad Mollah" had broken out, and the western route proposed by myself proved to be the only one possible, as the foreign office was forced to recall its permission to penetrate the hinterland of Berbera, and we were therefore obliged to set out from Zeila by the old caravan route to Harar. The members of the expedition were Baron Carlo von Erlanger, Dr. Hans Ellenbeck as physician, Mr. Johann Holtermuller as cartographer, Mr. Carl Hilgert as taxidermist, and myself.

We started from Zeila on January 12, 1900, but an accident to Mr. Carl Hilgert, who nearly killed himself with a small Flaubert gun, stopped us at the wells of Dadab, only three marches from the coast, so that we did not arrive at Harar until the beginning of March.

In the desert Baron Erlanger and myself preceded the caravan in order to meet Mr. Alfred Ilg, the foreign minister of the Emperor Menelik, who was on his way to the coast, and to whose valuable help a great part of the success of our expedition is due. But in the first place we have to thank the Emperor Menelik, that intelligent ruler and restorer of an ancient and great Empire, for his help and permission to pass through his country. In the second place our thanks are due for the kind assistance afforded by Major (now Lieutenant-Colonel) Harrington, H. B. M., agent in Abyssinia; Major Ciccadicola, the Italian envoy, and Mr. Muhle, postmaster and chief engineer of the telegraph and telephone lines between Adis Abeba and Harar.

From Harar we made an excursion to the mountains of Gara Mulata, situated about three days to the southwest and not visited by any European since the time of Captain Hunter. The western slopes of

[a] Read before the Royal Geographical Society, June 9, 1902. Reprinted from The Geographical Journal, London, Vol. xx, No. 4, October, 1902.

this range are covered with thick forest, and therefore the fauna, as well as the flora, here contrast sharply with that which we had found in the dry Somali desert between Zeila and Jildesa, situated at the foot of the Harar Mountains. Returning to Harar, the first thing we found was a prohibition to continue our journey to the south, as the countries of the Ennia and Arussi Galla were said to be in a state of rebellion, excited by that of the Somal; and only after a solemn declaration on our part to the effect that the Emperor Menelik should not be held responsible for our safety, and thanks to the great assistance of Major Harrington, did we receive permission to continue our journey. Unfortunately we were again obliged to put off our departure, as a great many of our camels, which during our sojourn in Harar had been left at a place in the Erer Valley, had died there from the results of eating poisonous herbs and it was impossible to obtain new animals for some time. We therefore made a temporary camp at Gandakore, in the country of Argobba, to the south of Harar.

It is remarkable that, in spite of their proximity to Harar, next to nothing was known of the interesting Argobba people and their old stone buildings. The remains of this probably once powerful nation dwell on the eastern slopes of the Hakim, a mountain ridge situated to the south of Harar. Their houses were built of stone, had high watchtowers in the center, and were surrounded by strong walls. They are now mostly fallen into decay and are only partly inhabited. The old ruins overlooking the Erer Valley resemble medieval castles and present a picturesque appearance. Scattered amongst them are the straw huts of the Ala Galla, who form the greater part of the population of to-day. Mysterious reports as to the Argobba exist among the Harari and the Galla. It is said that at certain festivals they devour human flesh. It is certain that these reports are untrue, as the Argobba are strict, even fanatical, Mohammedans, but they seem to prove that the nation is of quite a different origin to the inhabitants of Harar.

On May 22 we set off southward from Gandakore, and on the next day we passed the village of Biaworaba. The Austrian explorer Paulitschke had pushed as far as this place in the year 1884, but since that time no European had reached it or explored farther south, as the Abyssinian Government had strictly forbidden any European to enter that country. South of Biaworaba we entered the country of the Ennia. This people is a mixed race of Galla and Somal. They speak a Galla dialect, but have followed the nomadic manner of living of the Somal. For one or two years they build for themselves square huts of cow dung, much resembling those I found during my journey in East Africa in use by the sedentary Masai, the so-called Wakwafi. Besides these, they build for their cows and sheep peculiar huts, 7 to 8 feet high, resembling a sugar loaf, likewise of cow dung. Sometimes,

but seldom, they cultivate small tracts of land. These people are rather poor, and they are therefore mostly left in peace by the Abyssinians. At the time of our visit they were in extremely poor circumstances, as different parties of the Ogaden Somal had crossed the river Erer some months before and had carried off many of their cattle. On the whole, the country is a high plateau, thickly grown with bush and intersected by two tributaries of the Wabbi, the Gobele and the Moyo, which have cut deep, canyon-like clefts in the tableland. On the banks of the Moyo we found some beautiful grottoes, and I must also mention the remains of some old towns which we passed during this part of the journey. Here was formerly situated the Ethiopian frontier province of Daroli, which was devastated in the year 1528 by Mohammed Granye, the Sultan of Tajura—the "Attila of Africa," as he has been called. I must also note, at this point, that the river Shenon, marked on former maps, was not to be found, and was not even known by name to the Ennia people. And further, we discovered at several places between Harar and the Wabbi, especially near Harrorufa and Achabo, strata of Jurassic age containing numerous fossils, mostly in a splendid condition. On June 10 we were able to cross the river called Wabbi by the Galla, but better known by the Somali name Webi Shebeli—that is to say, the Leopard River.

On the farther bank of the Wabbi an event occurred which might have proved fatal to the success of our expedition. Our Somal, or a great part of them, had made up their minds to strike, as they feared our expedition would keep them too long from home. Perhaps they intended to go straight east and to join the revolting Ogaden tribes. By good luck I arrived just in time to stop the party from crossing the river with their rifles. They were afraid to return without them, and so, after a day's consultation, they agreed to go farther west with us. We were now in the country of the Arussi, a large and once much-feared section of the Galla tribe. Near a place called Gurgura we struck the route of Dr. Donaldson Smith, the first explorer of these countries, and followed it as far as the holy Mohammedan town of Sheikh Husein. Here, on the southern banks of the Wabbi, the bush was not so dense as on the north, and game was in some places abundant. We often found the fresh tracks of elephants, and near a place called Luku there were large herds of zebra (*Equus grevyi*), oryx and "gerenuk" (*Lithocranius Sclateri*), and plenty of the lesser kudu. The town of Sheikh Husein is well known from the wonderful description given in Dr. Donaldson Smith's book. When you approach it you already see from afar the white tombs of the sheikhs glistening in the sun. There are about twelve tombs altogether. In the middle there is a cemetery containing the tomb of the Mohammedan saint who is said to have founded the town, and whose name it bears. The inhabitants tell many stories of the miracles he did—for instance, he is

said to have piled up in one night a small mountain situated southeast of the town. The faces of the inhabitants show clearly that they are descended from old Arab colonists. Their chief is the Imam, a direct descendant of Sheikh Husein. The Christian Abyssinians, who for about ten or twelve years have been masters of these countries, treat the Mohammedans here and their traditions with much respect. Everything in and near Sheikh Husein is holy, and belongs to the dead sheikh. It is not permitted to cut wood near the town, no cattle are sold, and we were asked not to shoot birds. One of my Somal having caught two bats with a butterfly net in the holy tomb, a large assembly was held and the poor fellow and myself were cursed by the Imam until I gave him some dollars to appease the wrath of the dead sheikh. I will simply mention that, besides the tombs, there are other stone buildings in Sheikh Husein which, in my opinion, are perhaps of a pre-Islamatic origin, such as a wall about 2 feet thick surrounding a small lake near the town.

Prior to our arrival we had received messages from the Abyssinian dejasmach (General of the Center), Wolde Gabriel, the governor of these countries, ordering us, in the name of the Emperor Menelik, to proceed straight to Adis Abeba. Meanwhile we had lost so many camels by the rough roads in the Ennia and Arussi lands that we were compelled to leave here about half our stores. Directly west of Sheikh Husein there was no road practicable for camels, so we had to proceed two days in a southwesterly direction, crossing the beautiful and forest-clad chain which Dr. Donaldson Smith has called the Gillet mountains. The forests here show nothing of the character of a tropical African forest. Looking at the tall fir-like juniper trees, among which, in some places, the barley fields of the Arussi are scattered, the traveler might imagine himself in the Black Forest or in the forests of Tyrol. West of the Gillet mountains is an isolated mountain called Abunas, or Gara Daj, by the Arussi, which we ascended after some quarrels with the Abyssinian chief whom Wolde Gabriel had sent us as escort. This fellow seemed to be afraid that we might run away on the other side of the mountain. On the top of the Abunas there are ruins of a sanctum probably of pre-Islamitic age. The view here is splendid, and boundless on every side except the north, where Mount Abulkassim, about 900 feet higher than Abunas, is situated. From the summit we descended to the Wabbi, recrossed the river to the north, and camped about halfway up Mount Abulkassim, the holy mountain of the inhabitants of Sheikh Husein.

This mountain, already seen from a very far distance fifteen years ago by the Italian explorer Ragazzi, had never before been visited by any European. There is a good way leading upward to a high precipice, in which are about a dozen caverns, at some seasons of the year

inhabited by Mohammedan pilgrims. In one of these we found a stool, a mortar with pestle, and a wooden pillow. Not far off is the grave of Sheikh Abulkassim, a descendant of Sheikh Husein, made in an artificial bower situated in a wonderful tropical forest full of lianas and palms. The grave is covered with glass beads and ornaments of copper and brass. Similar ornaments are also to be seen on some trees in the forest, and no visitor would dare touch these holy objects. Round the mountain there is no settlement whatever.

From Abulkassim we proceeded west for about three days on the hills situated on the northern bank of the Wabbi. Near a place called Jaffa we were stopped by a large body of Abyssinians sent by the dejasmach Lulsagit, through whose countries we had now to pass. It took us some trouble to get permission to proceed farther, as the dejasmach had had no notice of our arrival. Here we had to ascend the last step of the plateau, and found ourselves on a large grass-covered expanse, absolutely flat and without any trees, called Didda by the inhabitants. On old maps this plain is called the Arussi plateau. The Northwestern Arussi, who live here, are a pure Galla tribe, showing no mixture of Arab blood, as do the inhabitants of the Sheikh Husein district. The sight of these dirty, long-bearded men galloping their small ponies, covered with brass and iron rings, over the wide plain, reminds one of Mongolian or Tartar tribes rather than of an African people. Their huts are scattered in small groups of three to five all over the plain. They do not cultivate much ground, but have large herds of fine cattle. Just as we arrived here the rainy season broke out with terrible vehemence, and the plain was soon changed into a large swamp, so that we here lost nearly half our camels. The crossing of this plain took us twelve days, after which we descended into the valley of the Hawash, which had overflowed its banks and in some places changed the valley into a large lake. I will here mention the church Georgis, in the district Sire, which was formerly a Mohammedan mosque, but is now changed into a Christian church by the Abyssinians. It might have been supposed that the country between the Hawash and the Abyssinian capital was absolutely known, as many explorers, including the Italians Traversi and Ragazzi and the German Stecker, had visited it. We were all the more surprised to find here a magnificent waterfall unknown before. The river Modsho, a small northern affluent of the Hawash, which is here about 500 feet broad, falls over a precipice 40 feet in height.. We called this waterfall, which I consider to be one of the most beautiful in northeastern Africa, Menelik Falls. Passing by Lake Buchoftu, one of a group of five small crater lakes called the Adda lakes, we arrived in Adis Abeba on August 14.

The Emperor Menelik promised us free permission to travel in his countries, and any assistance we might require. Owing to the fact that

our journey from Zeila to Adis Abeba had taken us nearly double the time we had at first calculated, Baron Erlanger and I came to the conclusion that it was impossible for us to accomplish together all our proposed programme. We therefore decided to divide our caravan, in order to explore as large an extent of unknown ground as possible. Baron Erlanger proposed to return by another route to Sheikh Husein, and to strike thence to Lake Rudolf by a new route, while I made up my mind to first penetrate the highlands of Shoa proper, and afterwards to find a new route somewhere westward to the Sudan.

For the moment traveling was out of the question, it being the height of the rainy season; but as soon as the rain began to slacken I formed a small caravan and started for the unknown part of Shoa which lies between the rivers Guder and Muger, two large southern affluents of the Blue Nile. Two days from Adis Abeba I passed the place Ejere', then a small village, but soon to become the new residence of the Emperor Menelik under the name of Adis Halem—that is to say, the "new world," the scarcity of wood near the old capital Adis Abeba ("new flower") becoming each year more and more apparent. Near Ejere, and still more in the district of Cheracha, there are magnificent large forests. After passing these I came to the district of Kollu, and stopped some days near a village called Aveve, as the place was noted for the presence of lions. I found some fresh tracks, but did not get a chance of seeing one. Here I found the source of four small rivers not previously known, the Urga, Gora, Taranta, and Bussiyo, which afterwards unite under the name Taranta to form a rather large river, which then flows westward to the Guder. The Bussiyo forms the frontier between Kollu, belonging to Shoa proper and the province of Gindeberat, which belongs to Gojam, the land of the since deceased king Tekla Haimanot. I will here mention the interesting basalt mountain called Badattino, on the top of which there are a village and a church. From here to Abuye, an Abyssinian fort situated on the edge of the plateau, the country has the character of a beautiful English park. I had to leave the bulk of my caravan at Abuye, as the road thence down to the Blue Nile was not practicable for fully laden mules, and descended with only seven men and a small tent. The difference in height between Abuye and the Blue Nile is about 5,800 feet. The river was now in flood and turbulent, making it quite impossible to cross to Gojam. Great heat prevailed in the valley, and we were terribly bitten by mosquitoes. I therefore gave quinine to all my men, and it was interesting to find that one who refused to take it got an attack of malaria after six days. Having reascended the plateau, I returned by the same way to Badattino, and thence took another route straight eastward.

Near a village called Adaberga I arrived to witness the end of a religious ceremony of the Galla. The Galla are split up into some

FIG. 1.—BASALT ROCKS NEAR LASMAN, BRITISH SOMALILAND.

FIG. 2.—MENELIK FALLS.

FIG. 1.—FIRST VIEW OF THE BLUE NILE NEAR ABUYE.

FIG. 2.—THE SUKSUK RIVER.

large divisions, and these again into smaller tribes, which are at the same time religious communities. Each of these tribes has its high priest, or Gallan, who resides near a sacred grove. On certain days of the year the Gallan shuts himself up in his house, and after working himself into a state of ecstasy makes inspired communications to the people standing around. The Christian Abyssinians are forbidden by their priests to attend these ceremonies; nevertheless, they believe in the mysterious power of the Gallan, whom they hold to be in league with the devil. The Gallan here was an interesting-looking man, standing over 6 feet high, with long hair and beard. From Adaberga I went to Falle, a place given by the Emperor Menelik to Mr. Ilg, and here I stopped some days to observe and collect specimens of the black Jellada baboon, a species not previously met with, which lives on the rocks of the steep precipices leading to the Muger River. After four weeks' absence I returned to Adis Abeba, and now prepared for my expedition to the Sudan.

The route I chose did not lead directly westward, because the chain of lakes situated in the northern part of the great East African rift valley seemed to offer some interesting geographical problems, as the existing maps on that part published by the Italians Traversi and Bòttego, by the Frenchman D'Aragon, by Donaldson Smith, by the late Captain Wellby, and a new one published by Count Leontieff, which came into my hands just before starting from Adis Abeba, could not be brought into agreement with each other. By the different position assigned on these maps to the lakes situated between Lake Zwaï and the large Lake Abaya, called Lake Margarita by Bòttego, I calculated that there ought to be one or even two lakes in that region not yet known. This calculation was afterwards confirmed by the discovering of Lake Langanna or Korre and the double Lake Abasi.

I left Adis Abeba on November 14, and at Mount Zekwala met the caravan of Baron Erlanger, who had started some days previously. The Hawash was now so low that we easily marched through it. From here to Lake Zwaï the country is covered with typical acacia bush, in the middle of which I found the grass and moss-covered ruins of an old Abyssinian settlement. Round Lake Zwaï, and on down the whole of the rift valley, as far as I followed it, game was plentiful. On the hills and mountains bordering the valley we have the large kudu, while farther south, at Lake Abaya, there is the lesser kudu. We saw on the plains the East African zebra (*Equus granti*), hartebeest (*Bubalis swaynei*), and Grant's gazelle; in the forests, elephants and rhinos. The reeds bordering the lakes are inhabited by large herds of water-buck and reed-buck.

The region near Lake Zwaï is very interesting from a geological point of view. We are here at the northern end of the great East African rift valley, which extends south to the middle of German

East Africa, finishing near Mount Gurui. The mountains bordering the valley at this northern part consist mostly of obsidian and other volcanic vitrified rocks. Some smaller rocky hills standing out in some parts of the valley also consist of the same material. The river Suksuk joins Lake Zwaj with the more southerly situated Hora Shale. Lake Hora, as it was called by the late Captain Wellby, is wrong, for Hora means "Salt Lake;" Hora Shale, "Pelican Salt Lake." South of it is the Hora Lamina, the water of which, as we were told by the Galla, has the same salty properties as has the Hora Shale. There is only a small neck of land between these two lakes, in the middle of which lies Mount Fike, a volcano of the typical horseshoe form, with its opening turned northward. Southeast of Lake Zwaj lies the Alutu, a mountain which consists in its upper parts almost entirely of a greenish-black obsidian-like rock. I made the ascent and saw from the top, east of Hora Shale, a lake previously unknown, which was called by the Arussi who accompanied us Hora Langanna, or Hora Korre. This is the most beautiful of the lakes, as the southern slopes of Mount Alutu fall in picturesque contour into the water. There is a connection between this lake and Hora Shale, which is called Daka by the Arussi. I reached the Hora Korre on the next day. Its waters are only slightly brackish. South of Hora Korre I found the most magnificent euphorbia forests I ever saw in Africa. Near a great market place called Alelu I marched for about five or six hours, hardly seeing any other tree. Arriving at Lake Abassi (which, although seen by d'Aragon, is not to be found on any recent map, probably because it was considered identical with the Lake Lamina of Captain Wellby) my caravan and that of Baron Erlanger were stopped by the Balambaras Abite, a subchief of the Dejasmach Balcha, the Abyssinian governor of these countries. In spite of the permission given in the Emperor Menelik's letters, we had to send messengers ahead to the dejasmach in order to ask his permission to come to his residence. It took them five days to return. I used that time in making investigations of the hot springs which are situated at the eastern corner of the lake. Some of these had formed hills of tuff 10 feet high. The substance is about the same as that of the Karlsbad-Sprudelstein. The hot water bubbles out at the summit.

Here we entered a new ethnological region, that of the Sidamo people. The Sidamo form one group with the Jamjam, Walamo, Borodda, Kosha, and Malo people on the banks of the Omo River. This is a group of a probably very remote origin, but more or less mixed with conquering Galla tribes. Ascending from the north we had to pass wonderful forests covering the western slopes of a high mountain chain, till we reached the plateau covered with alpine marsh and bamboo forest on which Abera, the "Katama," or residence of the Dejas-

mach Balcha, is situated. Abera lies about 10,000 feet above the sea level and is three hours north of the old capital Daressa, visited by d'Aragon. Looking northward one has good views back as far as Lake Abassi; looking westward you have glorious views of Lake Abaya or Margarita, with the mountainous countries of Walamo, Borodda, and Gamo on its western shore.

The reception the dejasmach had prepared for us was most magnificent. Hundreds of horsemen dressed picturesquely came out to meet us. Between our camp and the bamboo palace of the dejasmach there was a double line of Abyssinian warriors in full attire, dressed with silk skirts interwoven with gold or silver, or covered with lion and leopard skins. Hundreds of shields, covered with gold and silver ornaments, glistened in the sun. The dejasmach wished us to continue our journey by the great Abyssinian road running south along the ridge of this large mountain chain, but I intended to descend to Lake Abaya, in order to have some shooting, and to visit one of the large islands in the lake. It was long before the dejasmach would give permission for this. He told us dreadful stories of the bad roads, the absence of food near the lake, and the number of people killed by lions there. The reason for these stories probably was that he was afraid that we would shoot too many elephants, of which we afterwards found large herds on the shore of the lake. Descending I passed the country of the Gudji, or Uata Dera, who in their physiognomy reminded me very much of the Wandorobo tribe of East Africa.

Quite a different population called Gidicho live on the largest island of the lake. The Gidicho have good-looking, Somali-like faces. My Somal found, to their great astonishment, that a great part of the Gidicho expressions were almost identical with their own; as, for instance, the words for the various parts of the body and for the best-known animals, such as lion and leopard. I consider this discovery to be of great importance from an ethnological point of view, as the Somal were always thought to be the last intruders in Northeast Africa, and here we find an isolated tribe surrounded by a population of an apparently older origin. The boats of the Gidicho are very interesting. They are rather rafts in boat form, being made of the very light wood of a species of ambach. The bow is often ornamented like that of the Venetian gondolas. Formerly there were constant quarrels and wars between the inhabitants of the islands and those of the shore, but now, under Abyssinian rule, all live in peace with each other.

At Lake Abaya my caravan separated from that of Baron Erlanger, who had to return to Abera and Sheikh Husein. South of Lake Abaya lies Lake Ganjule, whose water has a wonderful dark azure blue color, and may be compared to the most beautiful lakes of Switzer-

land. I had resolved to pass along the eastern shore of Lake Ganjule, in order to solve the problem of the sources of the river Sagan, the largest affluent of Lake Stefanie, which was supposed to flow out of Lake Ganjule. This I found to be not the case. The sources of the Sagan lie east of the south end of Lake Abaya. But there is a broad channel connecting Lake Ganjule with the Sagan. The bed of this channel was dry at the time, but there were some large and small water pools scattered over it. When the water rises in Lake Ganjule for about 5 inches, which will probably take place every year at the beginning of the rainy season, a large river will run from Lake Ganjule to the Sagan. On the upper Sagan I again found some hot sulphurous springs. It was impossible to follow the course of the Sagan, as it runs at some places through densest forest, the haunt of rhinos and buffaloes, the tracks of which were to be seen everywhere. I went round the south corner of the lake and ascended the mountains of Gardulla, which I reached in the second week of January, 1901.

The Gardulla were the first people of Bantu stock that I met. The difference can be seen at first glance in their heavier and stronger built figures and their nearly black skin. While working in the fields the men go quite naked, in the villages they wear skins and cotton stuffs. Cotton is the principal cultivation of Gardulla and of most countries northward to Kosha and Konta, while farther north Kaffa and Jimma are the first coffee lands of Africa. As the hills of Gardulla are very stony, the inhabitants range the stones in terraces, so that a Gardulla hill has the aspect of a vineyard on the Rhine. They have their houses and the walls surrounding them made of broad, plain planks, and on the top of the reed roof there is as ornament a red earthenware vase. The land was formerly under a queen, who still lives in a place called Gidole. The Abyssinians still allow her to exercise her authority in petty affairs, but she has no further influence whatever. The true ruler of the land, the Futarari Wolde, is a subchief of Futarari Afta Georgis, to whom the Emperor Menelik gave these countries when conquered, but who prefers to remain in Adis Abeba. The Gardulla wear broad necklaces of brass or copper. The women wear bracelets, necklets, and rings round fingers and toes, made of small red and blue beads. In Gardulla I saw the first camels since my departure from Adis Abeba. Futarari Wolde has a large herd of these animals, obtained from the countries of the Bovana and Tertale, near Lake Stefanie, which are kept in a place at the foot of the mountains. Westward of Gardulla there is a large uninhabited plain, called by the Abyssinians "Adoshebaï."

The spirit Adoshebaï of the Abyssinians combines the qualities of a devil and patron saint of the hunters. They call upon Adoshebaï when they have killed a lion, elephant, rhino, giraffe, or buffalo, and even a poor Shankala—that is to say, any of their large game. I may here

mention that the Abyssinians call Shankala not only the tribe called Beni Shongul by the Arabs, living on the western banks of the river Dabus, but all the Sudanese and black people living in the countries round Lake Rudolf and near the Omo. That is all dark-colored people with the exception of the Somal and the Galla.

There is a legend that, when the Abyssinians conquered this country about seven years ago, two elephant hunters were descending from the "Katama" Gardulla to the large plain to the west. They had the luck to kill one of the large pachyderms near a small hill, and called on their patron saint, when suddenly the hill began to dance and sing. "Adoshebaï, Adoshebaï." So they now look upon the plain as the home of this spirit. The Abyssinians had also told me of a dangerous disease, which would kill all our mules and horses, by which this plain is haunted. Nevertheless, I determined to cross it, as otherwise I should have had to follow hence, as far as the Omo, the route taken by Captain Bòttego. But I marched straight on without spending much time in hunting the game, which was abundant here. Elephants, rhinos, buffaloes, large herds of zebras, and hartbeests of a species new to science, were seen. In the night we were disturbed by the roaring of the lion.

After two days' marching we came to a river called Shambala by the Abyssinians of our escort. On the other side we saw natives running away from their cotton fields in terrible fright. We were here in the country of the Male, which may be identical with the Mela mentioned by Donaldson Smith. The Male are not yet absolutely subjected by the Abyssinians. I gave presents to some old men and women, who were not quick enough to run away, and sent them back to their fellows, but I was not able to have any intercourse with the people, as the next day nobody appeared. Here I found, for the first time, bows and poisoned arrows, while in all the countries passed before the spear and sword were the only arms. Crossing the Barsa, another river flowing, like the Shambala, into Lake Stefanie, we came to Uba, a part of the equatorial province given by the Emperor Menelik to the Abyssinian count and Dejasmach Leontieff. There is a good fort in Uba, built by the brothers Seljan, now officers of Count Leontieff, formerly musicians and professional pedestrians. Neither of the two brothers were here, as they were recalled to Adis Abeba by the Emperor on account of some differences they had had with the natives.

In Uba the illness which the Abyssinians had feared in the plain of Adoshebaï broke out among the mules. I had thought before that it might be the tsetse fly disease, but it now became clear that it was the glanders. This disease seems to be endemic on all the northern affluents of Lake Stefanie, as is shown by the experience of the late Captain Wellby, who lost most of his animals after passing the same region. I descended into the beautiful valley of the river Zenti, covered with

thick forest and magnificent palm trees, which separates Uba from Gofa. The Zenti runs northward into the Omo.

Every day more of my mules and horses became afflicted with the disease, and many of them died. The representative of Dejasmach Lamma, the governor of Gofa, who was at the time in Adis Abeba, sent me native porters, who helped me to carry the baggage up the mountains of Gofa, which reach an altitude of about 10,000 feet above sea level. At a place call Gadat, near the capital Jala, I stopped for two weeks, and, in order to master the disease, isolated the sick animals and divided the others into small bodies. After that time I had saved about 25 out of 60. Meanwhile I had sent my Abyssinian headman with a small escort to Adis Abeba, with orders to buy new mules and horses there, and to come back as quickly as possible to Anderacha, the capital of Kaffa, which I had designed to be my starting point for the unknown lands in the west. From Gofa to Kaffa the expedition went on very slowly, because I was now dependent on native porters, whom I got by order of the Abyssinian governors from the smaller native chiefs, and who had to be changed when we came into the land of another chief, which was always after one or two days' short march. Crossing the rather bare valley of the Ergino, another affluent of the Omo, I came to the country of Doko.

The Uba and the Gofa, through whose countries I had passed, until here belong to the Wallamo tribe. The Doko are typical Bantu, and seem to be nearly related to the Gardulla. The men walk about absolutely naked, the women wear an apron made of cut banana leaves. They know how to weave cotton stuffs well, but seldom use them themselves. North of Doko is the country of Malo, inhabited by a Wallamo tribe. Hence, I descended to the Omo, which I managed to cross within two days, on rafts resting on inflated goatskins. In this region there is not much forest on the shores of the river, as the banks consist of gigantic gneiss blocks. At no place in Africa have I seen so many hippos as here. Walking down the banks I saw in half an hour more than a hundred heads appearing above the surface of the water. Every stony bank in the river was occupied by a family of these clumsy animals. They are not hunted here, and therefore not at all shy.

North of the river lies the country of Kosha. Kosha and the neighboring Konta are the only provinces I found in Abyssinia where the slave trade is in full swing. At the large weekly markets you can see—besides cotton, coffee, flour, goats, and sheep—children sold in small or large lots. It is probable that this trade is due to the great famine by which these countries have been stricken during the last two or three years, and the children all seem to be quite happy at becoming the property of richer men, with whom they will be better fed. The houses of the Kosha chiefs are very interesting. They are long barn-

FIG. 1.—BOAT OF THE GIDITSCHO, ON LAKE ABAYA.

FIG. 2.—LANDSCAPE IN GARDULLA.

FIG. 1.—MARKET IN DOKO.

FIG. 2.—OMO RIVER BETWEEN MALO AND KOSHA.

like structures, about 15 feet high and 50 to 60 feet long, entirely covered in with grass. Here the rainy season was ushered in by terrible tempests, and for the next two months we had thunderstorms nearly every day. Near a place called Dereta we passed the "Kella" or gate of Kaffa.

These south Ethiopian kingdoms—Kaffa, Jimma, Gera, and Enarea of which we have still but an imperfect knowledge from the journeys of the Italian Cecchi and the Frenchmen d'Abbadie and Borreli, are separated from each other by an interesting system of fortification. Where the countries are not bounded by high mountain chains, difficult to cross, they are surrounded by deep ditches and strong fences, which can only be passed by means of a guarded gate called the "Kella." The Abyssinians, after having taken these countries, retained this system of fortification and the custom duties between the different countries. The export of slaves is absolutely forbidden, that of cattle only allowed by permission of the governor. The whole south of Kaffa is one large forest; there is a broad road leading from the Kella to Anderacha, the new capital. It is absolutely impossible to penetrate the forest which borders the road without using axes or bush knives. Scattered in clearings in the forest are the villages and coffee plantations of the inhabitants, the Kaficho. These are said to be the descendents of the old Ethiopians, who were isolated when Mohammed Granye, Sultan of Tajura, smashed the old Ethiopian Empire, in the years 1528–43. It is a fact that most of the Kaficho were Christians when the Emperor Menelik conquered Kaffa, about five years ago. Also the "Gez," the ecclesiastical language of the Abyssians, was still in use, but the language used by the Kaficho of to-day has no affinity whatever with the modern Abyssinian. Kaffa was formerly ruled by powerful independent kings, to whom also nearly all the countries west of the Omo were subject. The last king, Savo Teheno, who had submitted some years ago to Menelik, revolted, was defeated by the Abyssinians, and brought as prisoner to the old Abyssinian capital Ankober, where he still lives. Kaffa and all the countries south of the Gojeb and west of the Omo were given to Ras Wolde Georgis, one of the favorites of Menelik. Kaffa was formerly the principal coffee-producing land in Africa, but when the Abyssinians took the country many of the plantations were destroyed, and it is now inferior in that respect to the Kingdom of Jimma. The national dress of the Kaficho formerly consisted of long capes of reed, grass, or hemp. The men wear hats made of goat and colóbus monkey skins; the women conical hats of bast. These national costumes are now seldom seen in Kaffa, where the inhabitants dress like the Abyssinians, but they are still exclusively used in the tributary land of Gimirra, in the west.

My headman reached Anderacha ten days after my arrival, and brought with him some new men and some mules; but now my most

terrible time began. Nearly all the Abyssinians, and also my 13 Somal, struck and refused to proceed to the unknown countries westward, where they said they would all be killed. They went to the Abyssinian chiefs swearing that they had only been engaged up to Kaffa. The small Abyssinian chiefs (Ras Wolde Georgis and his chief officials being in Adis Abeba at the time) sympathized with my men, as, in spite of the Emperor's permission, they were afraid to let a European go out of the country. Much patience, much money, and many promises were needed to persuade my Somal and about half of my Abyssinians to remain with me. As I was, therefore, in want of new men and also new mules and horses, I had to make an excursion to Jimma, adjoining Kaffa on the northeast, and separated from it by the river Gojeb, an affluent of the Omo. Approaching the Northern Kella of Kaffa, I found everywhere evidences of the last war with the Abyssinians. Near the road I saw strong fences and deep ditches, while the forest was virtually honeycombed with holes about 10 to 12 feet deep, with a pointed stake in the middle of each.

Jimma is almost the richest land of Abyssinia. The inhabitants are pure, well-built Galla. They are nearly all Mohammedans, as well as their king, Aba Jifar, a very clever man, who at the right time submitted to Menelik, and therefore retained his country. King Aba Jifar, who helped the Abyssinians very much in conquering Kaffa, is now in great favor with the Emperor. The capital of Jimma is Jiren, the most important market place in Abyssinia. I estimate that the Thursday market in Jiren is visited by nearly twenty to thirty thousand persons. From all the countries bordering the river Omo, and even from Adis Abeba, and other lands in southern Ethiopia, the Nagadis or Abyssinian merchants meet in Jiren to sell their wares. All the products of southern Ethiopia are sold there, in many double rows of stalls about a third of a mile long.

Having enlisted 20 strong men and bought some dozens of mules and horses, I returned to Anderacha and started thence in the first week of April. Gimirra, which we reached first, is a tributary land to Kaffa; the people seem to be Kaficho, perhaps with a mixture of Nilotic blood. Their old king, Chotatu, and some of his companions are nearly 6½ feet high. They wear the national dress of Kaffa, already described. The men often wear necklaces, with a string of Hyrax teeth hanging down their chest. In Gimirra is the last Abyssinian post. The people of Binesho, which we passed next, are in friendly relations with the Abyssinians, who will probably soon take possession of the country; the people of Shekho, which lies west of Binesho, are only another branch of the Binesho, but are absolutely independent, and the land is often plundered by Abyssinian razzias.

The Binesho and the Shekho are of the Bantu stock, but are, perhaps, the most interesting tribes I ever met. Their language is hard

FIG. 1.—PART OF JIREN MARKET (DJIMMA).

FIG. 2.—SCHEKHO HUT.

and sharp sounding. Their figures are broad and muscular; they have different kinds of tattooing on the chest and on the back, but their most interesting tattooing is on the forehead, in which they cut vertical slits, which gives them the aspect of wearing a horn. They often wear capes made out of grass, like those of the Gimirra, and also capes made of cut bark, and, to my great astonishment, I also found clothes woven of bark, similar to those worn in Uganda and Usoga. I never saw a woman, either in Shekho or in Binesho, probably because they are first placed in safety as the object most desired by the Abyssinians. I had to be very much on my guard here, as the Shekho were always lurking in the bushes, trying to cut off my men and kill them singly. Once they speared one of my horses while grazing, nevertheless I succeeded in avoiding any actual fighting.

In Shekho I found a large river running westward. I believed this river to be the Gelo, discovered near its junction with the Ajuba by the Italian Bòttego, an opinion which was confirmed afterwards. Traveling became very difficult here. The western slopes of the South Ethiopian plateau are cut by many deep ravines; the roads therefore were narrow and bad, and many of my mules became wounded and useless. As it flows westward, the river Gelo is lined on both sides by the densest forest. I could march only about 2 or 3 miles each day, and to cover that distance the men had mostly to cut the way with axes and bush knives from morning till noon, after which the caravan was able to proceed. The inhabitants of this forest are the Mashango, who were very seldom seen, but we often found large traps made for hippos and water bucks, and loops made of creepers for monkeys and other small animals going to the water. Already in Gimirra I had seen, far away to the west, a long mountain chain running from north to south, called by the Galla "Gurafarda"—that is to say, "horse's ear," from a sharp double peak in the middle. It took more than three weeks from Gimirra to reach the point where the Gelo pierces the mountains, forming magnificent cascades. Some days after passing this gap, I saw from a bamboo-covered hill in the west a boundless bush and grass-covered dead flat, the plain of the Sobat and the beginning of the Sudan. Only a few granite hills are scattered over it. Ascending one of these, I saw, far away, a large lake—Lake Tata—through which the river Gelo runs. Here we found the first villages of the Jambo, or Anyuak, who were the first true Nilotic people I met. They are a division of the great Shilluk tribe, which is spread over the whole eastern Sudan, and extends southward to the east shore of Lake Victoria. The few samples I obtained of their language show that it is scarcely distinguishable from that of the Kavirondo people on the east shores of Lake Victoria, whose country I passed on my first African journey in 1894.

The land now became more and more swampy. The Anyuak, poverty stricken through many Abyssinian razzias, live hidden away on small islands in these swamps. A large part of the people have migrated westward, and live in a state of semislavery under the protection of the more powerful Nuar near the Egyptian fort of Nasser, on the Sobat. Approaching Lake Tata, the swamps became so numerous and deep that I turned south and marched to the Akobo, or Ajuba, which river I reached near the village Gneum, where I struck Bòttego's route. The attempt to march along the northern bank of the Akobo failed, because we stuck fast in the swamps, where I lost many of my mules; so, after two days, I marched back to Gneum and crossed the Akobo. The country on the left shore of the river, which had here a northwesterly direction, was drier.

As at that time I had only the maps of Bòttego and Wellby, I concluded that the Akobo of Bòttego and the larger Ruzi of Wellby must be one and the same river. I therefore hoped to get from here to Nasser dry-shod, but, instead of turning to the north, as I expected, the course of the river after a few days took a due westerly direction, winding in and out over an immense grassy plain. I was now in a very bad plight; my cattle and flour had been a long time exhausted, the country was nearly uninhabited, and game, which had been plentiful on the first days on the river Akobo, became scarce. Glanders had broken out again, and every day more of my animals succumbed. Suddenly I reached the right bank of a slowly flowing river, full of crocodiles. It was now apparent to me that this was the Ruzi of Wellby, or, as it is called by the Nuar, the Pibor. It was impossible to cross the Pibor without boats; so I recrossed the smaller Akobo in the hope that, marching on the right bank of the Pibor, I might find villages with boats. My situation became now desperate; out of 65 animals with which I had left Gimirra, I had only 13 mules, 2 horses, and 2 donkeys left.

All the stores not absolutely necessary were thrown into the river. The same was done with all the tents except my own, as well as with my books and clothes, the only part of my belongings which I contrived to bring safely home being my collections, photographs, diary, and route books. The day after we had passed the Akobo, I had already dug a hole in which to hide an object which for the moment was only a useless weight—the tusks of an elephant I had shot in the Gurafarda Mountains—and I was just looking round my tent to see what more I could dispense with, when suddenly a great tumult arose in the camp. I snatched up my rifle, as I thought an elephant or a giraffe had come near the camp, but my chief Somali jumped in, crying, "Marka, marka."[a] Abyssinians, Galla, and Somal were scream-

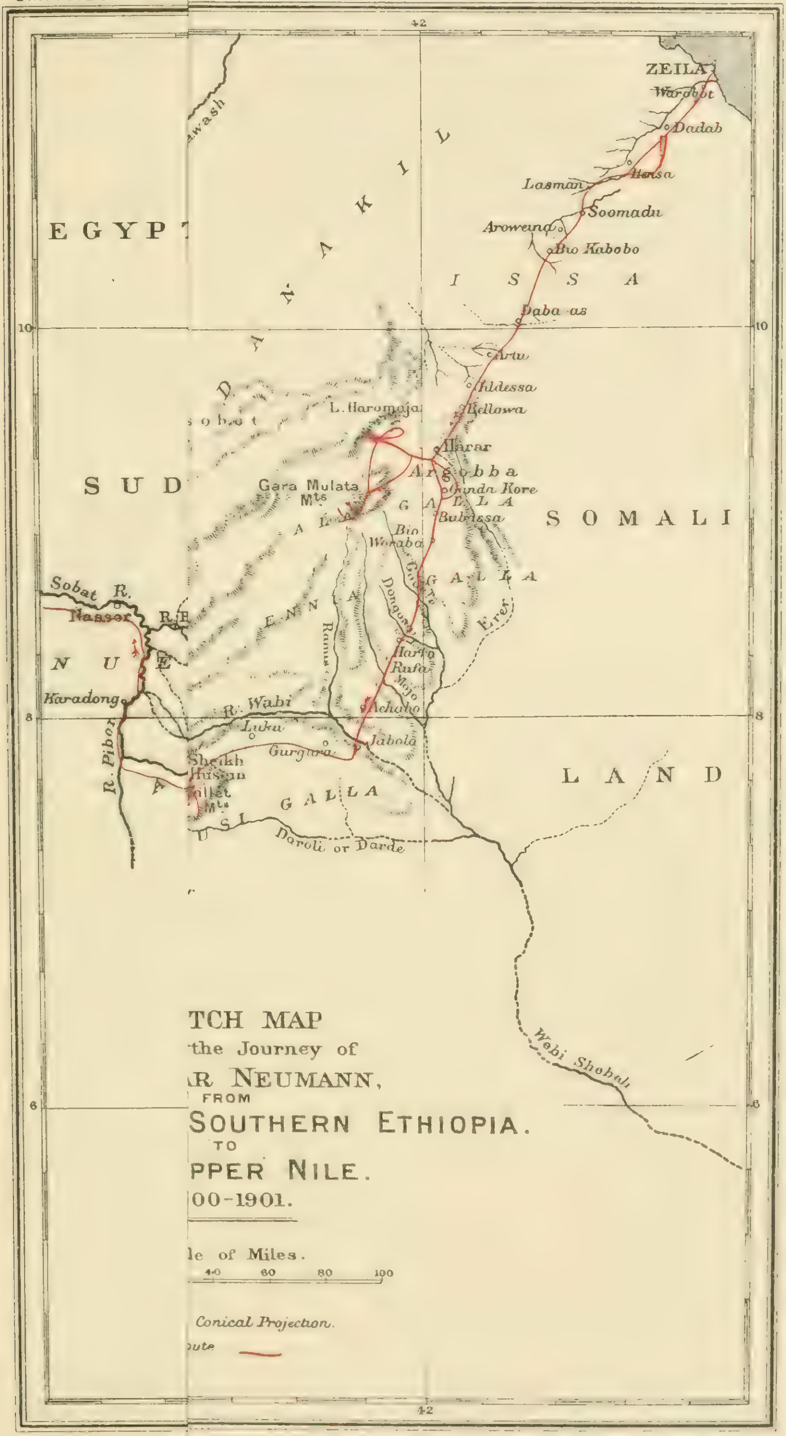
[a] "Steamer, steamer."

ing, crying, dancing, and firing their guns, all looking down the river. There was a steamer in sight, slowly approaching and filling nearly half the river bed. The Egyptian flag was flying from the mast and two Europeans stood at the bow. The steamer stopped alongside our camp and I welcomed the first of the Europeans in English, but on hearing my name he answered me in pure German. It was Sir Rudolf Slatin, and the other gentleman Colonel Bluett, the mudir of Fashoda. I went on board and everything was soon explained. Slatin Pasha and Colonel Bluett had come on a journey of inspection to Fort Nasser, on the Sobat, and thence they had had to proceed to a village called Karadong, on the Pibor, in order to settle some quarrels between two influential Nuar chiefs. On arriving here they had heard that a European was approaching with a large caravan and had decided to steam up the river in order to bring me assistance if required. They had found me when I was just at the last extremity. Had I come two or three days later I should have been forced to make my way to Nasser by land, which would have been a difficult task, considering the diseased state of my mules and the probable hostility of the Nuar, who had formerly been robbed by the Abyssinian raiders. There are still the ruins of a large Abyssinian fort near the junction of the rivers Akobo and Pibor. As one of my Somal had the day before shot a large bull giraffe, and my men had therefore provisions for four days, Slatin Pasha was kind enough to take me on board, with all my men and my collections. The surviving mules were given to the Nuar of Karadong.

The next day the steamer passed the point where, on the map of this region published by Major Austin in the Geographical Journal, 1901, the river Gelo joins the Pibor, but it was apparent that the small river flowing in here could not bring all the waters of the mighty river along which I had marched for four weeks. The Gelo probably divides after having passed Lake Tata; the northern branch, which is possibly the largest, running northward to the Baro, and the southern again dividing into two rivers, which flow to the Pibor.

Passing the small Egyptian fort Nasser and the famous Fashoda, one of the sorriest-looking places in Africa, we steamed down to Khartum. Broad green, fertile plains alternated with acacia-covered scrub steppes. On the banks of the river we saw villages of the Nuar, the Dinka, and the Shilluk, with their large rounded huts. Everywhere we saw absolutely naked women and men, the latter mostly painted white, boisterously greeting the steamer. There were large herds of cattle, sheep, and goats, and in the Arab districts of the lower White Nile, camels, horses, and donkeys. A picture of peace and plenty is the Egyptian Sudan of to-day. We arrived at Khartum on June 15, and I there enjoyed the charming hospitality of the sirdar, Sir Reginald Wingate. Here, also, I had the pleasure of again seeing

Captain Harold, who had given us much help in starting our caravan from Zeila eighteen months before. My Abyssinians were sent by steamer up the Blue Nile to Roseires, in order that they might return thence to Adis Abeba by way of Famaka. My thirteen Somal accom panied me to Cairo, and returned thence to Aden. * * * [Here follows a review of the purely scientific results of the journey.]


ZEILA
Warabot
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TCH MAP
the Journey of
R NEUMANN,
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SOUTHERN ETHIOPIA.
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SKETCH MAP
Showing the Journey of
Mr. Oscar Neumann,
from
Zeila through Southern Ethiopia.
to
The Upper Nile.
1900-1901.
Scale of Miles.
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Secant Conical Projection
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EGYPTIAN
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SOMALI
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ZEILA
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ADDIS ABBABA
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Gera
Sheikh Mohammed
Mt Abunasar
Mt Abulkasim
TURKANA
LAKE RUDOLF
Sobat R
R Abai
R Baro
R Gelo
R Akobo
Omo R
Soomadu
Daba as
Dudub
Loeman
Arrowna
Tio Kabobo
Webi Shebeli
R. Hawash

PRIMEVAL JAPANESE.[a]

By Capt. F. Brinkley.

There are three written records of Japan's early history. The oldest[b] of them dates from the beginning of the eighth century of the Christian era, and deals with events extending back for fourteen hundred years. The compilation of this work was one of the most extraordinary feats ever undertaken. The compiler had to construct the sounds of his own tongue by means of ideographs devised for transcribing a foreign language. He had to render Japanese phonetically by using Chinese ideographs. It was as though a man should set himself to commit Shakespeare's plays to writing by the aid of the cuneiform characters of Babylon. A book composed in the face of such difficulties could not convey a very clear idea of contemporary speech or thought. The same is true, though in a less degree, of the other two[c] volumes on which it is necessary to rely for knowledge of ancient Japan.

It might reasonably be anticipated, arguing from the analogy of other nations, that some plain practical theory would exist among the Japanese as to their own origin; that tradition would have supplied for them a proud creed identifying their forefathers with some of the renowned peoples of the earth, and that if the progenitors of the nimble-witted, active-bodied, refined, and high spirited people now bidding so earnestly for a place in the comity of great nations had migrated originally from a land peopled by men possessing qualities, such as they themselves have for centuries displayed, many annals descriptive of their primeval home would have been handed down through the ages. There are no such theories, no such annals, no such traditions.

[a] Reprinted, by permission, from "Japan. Its History, Arts, and Literature." Vol. I. Chapter II. Published by the J. B. Millet Company, of Boston and Tokyo.

[b] The Koji-ki, or annals of ancient matters.

[c] The Nihon-gi (history of Japan) and the Koga-shu (ancient records).

When the Japanese first undertook to explain their own origin in the three books spoken of above, so unfettered were they by genuine reminiscences that they immediately had recourse to the supernatural and derived themselves from heaven. Reduced to its fundamental outlines, the legend they set down was that, in the earliest times, a group of the divine dwellers in the plains of high heaven descended to a place with a now unidentifiable name, and thence gradually pushing eastward, established themselves in the "land of sunrise," giving to it a race of monarchs, direct scions of the goddess of light (Amaterasu). Many things are related about these heaven-sent folk who peopled Japan hundreds of years before the Christian era. They are things that must be studied by any one desiring to make himself acquainted with the essence of her indigenous religion or her pictorial and decorative arts, for they there play a picturesque and prominent part. But they have nothing to do with sober history. Possibly it may be urged that nations whose traditions deal with a Mount Sinai, a pillar of cloud and fire, and an immaculate conception, have no right to reject everything supernatural in oriental annals. That superficial retort has, indeed, been made too often. But behind it there undoubtedly lurks in the inner consciousness of the educated and intelligent Japanese a resolve not to scrutinize these things too closely. Whether or not the "age of the gods"—kami no yo—of which, as a child, he reads with implicit credence, and of which, as a man, he recognizes the political uses, should be openly relegated to the limbo of absurdities; whether the deities had to take part in an immodest dance in order to lure the offended sun goddess from a cave to which her brother's rudeness had driven her, thus plunging the universe in darkness; whether the god of impulse fought with the god of fire on the shores of the Island of Nine Provinces; whether the procreative divinities were inspired by a bird; whether the germs of a new civilization were carried across the sea by a prince begotten of the sunshine and born in the shape of a crimson jewel—these are not problems that receive very serious consideration in Japan, though neither a Colenso nor a Huxley has yet arisen to attack them publicly. They are rather allegories from which emerges the serviceable political doctrine that the Emperors of Japan, being of divine origin, rule by divine right. It is the Japanese historian's method, or the Japanese mythologist's manner, of describing an attribute claimed until very recently by all occidental sovereigns, and still asserted on behalf of some. As for the foreign student of Japan's ancient history, these weird myths and romantic allegories have induced him to dismiss it as a purely imaginary product of later-day imagination. The transcendental elements woven into parts of the narrative discredit the whole in his eyes. And his scepticism is fortified by a generally-accepted hypothesis that the events of the thirteen opening centuries of the

story were preserved solely by oral tradition. The three volumes which profess to tell about the primeval creators of Japan, about Jimmu, the first mortal ruler, and about his human successors during a dozen centuries, are supposed to be a collection of previously unwritten recollections, and it seems only logical to doubt whether the outlines of figures standing at the end of such a long avenue of hearsay can be anything but imaginary. Possibly that disbelief is too wholesale; possibly it is too much to conclude that the Japanese had no kind of writing prior to their acquisition of Chinese ideographs in the fifth century of the Christian era. But there is little apparent hope that the student will ever be in a position to decide these questions conclusively. He must be content for the present to regard the annals of primeval Japan as an assemblage of heterogeneous fragments from the traditions of South Sea Islanders, of Central Asian tribes, of Manchurian Tartars, and of Siberian savages, who reached her shores at various epochs, sometimes drifted by ocean currents, sometimes crossing by ice-built bridges, sometimes migrating by less fortuitous routes.

What these records, stripped of all their fabulous features, have to tell is this:

At a remote date a certain race of highly-civilized men—highly civilized by comparison—arrived at the islands of Japan. Migrating from the south, the adventurers landed on the southern island, Kiushiu, and found a fair country covered with luxurious vegetation and sparsely populated by savages living like beasts of the field, having no organized system of administration and incapable of offering permanent resistance to the superior weapons and discipline of the invaders, who established themselves with little difficulty in the newly-found land. But on the main island two races of men very different from these savages had already gained a footing. One had its headquarters in the province of Izumo and claimed sovereignty over the whole country. The other was concentrated in Yamato. Neither of these races knew of the other's existence, Izumo and Yamato being far apart. At the outset the immigrants who had newly arrived in Kiushiu imagined that they had to deal with the Izumo folk only. They began by sending envoys. The first of these, bribed by the Izumo rulers, made his home in the land he had been sent to spy out. The second forgot his duty in the arms of an Izumo beauty whose hair fell to her ankles. The third discharged his mission faithfully, but was put to death in Izumo. The sequel of this somewhat commonplace series of events was war. Putting forth their full strength, the southern invaders shattered the power of the Izumo court and received its submission. But they did not transfer their own court to the conquered province. Ignorant that Izumo was a mere fraction of the main island, they imagined that no more regions remained to be subjugated. By and by they discovered their mistake. Intelligence reached them that far

away in the northeast a race of highly-civilized men, who had originally come from beyond the sea in ships, were settled in the province of Yamato, holding undisputed sway. To the conquest of these colonists Jimmu, who then ruled the southern immigrants, set out on a campaign which lasted fifteen years and ended, after some fierce fighting, in the Yamato ruler's acknowledging their consanguinity with the invader and abdicating in his favor.

Whether Jimmu's story be purely a figment of later-day imagination, or whether it consists of poetically embellished facts, there can be no question about its interest, since it shows the kind of hero that subsequent generations were disposed to picture as the founder of the sacred dynasty, the chief of the Japanese race. The youngest of four sons, he was nevertheless selected by his "divine" father to succeed to the rulership of the little colony of immigrants then settled in Kiushiu, and his elder brothers obediently recognized this right of choice. He was not then called "Jimmu;" that is his posthumus name. Sanu, or Hiko Hohodemi, was his appellation, and he is represented in the light of a kind of viking. Learning of Yamato and its rulers from a traveler who visited Kiushiu, he embarked all his available forces in war vessels and set out upon a tour of aggression. Creeping along the eastern shore of Kiushiu, and finally entering the Inland Sea, the adventurers fought their way from point to point, landing sometimes to do battle with native tribes, sometimes to construct new war junks, until, after fifteen years of fighting and wandering, they finally emerged from the northern end of the Inland Sea and established themselves in Yamato, destined to be thenceforth the imperial province of Japan. In this long series of campaigns the chieftain lost his three brothers. One fell in fight; two threw themselves into the sea to calm a tempest that threatened to destroy the flotilla. Such are the deaths that Japanese in all ages have regarded as ideal exits from this mortal scene—deaths by the sword and deaths of loyal self-sacrifice. To the leader himself, after his decease, the posthumous name of Jimmu, or "the man of divine bravery," was given, typifying the honor that has always attached to the profession of arms in Japan. The distance from this primitive viking's starting point to the place where he established his capital and consummated his career of conquest can easily be traversed by a modern steamer in twice as many hours as the number of years devoted by Jimmu and his followers to the task. That the craft in which they traveled were of the most inefficient type may be gathered from the fact that the viking's progress eastward would have been finally interrupted by the narrow strip of water dividing Kiushiu from the main island of Japan had not a fisherman seated on a turtle emboldened him to strike seaward. Thenceforth the turtle assumed a leading place in the mythology of Japan—the type of longevity, the messenger of the marine

deity, who dwelt in the crystal depths of the ocean, his palace peopled by lovely maidens. The goddess of the sun shone on Jimmu's enterprise at times when tempest or fog threatened serious peril, and a kite, circling overhead, indicated the direction of inhabited districts when he and his warriors had lost their way among mountains and forests.

How much of all this was transmitted by tradition, written or oral, to the compilers of Jimmu's history in the eighth century; how much was a mere reflection of national customs which had then become sacred, and on which the political scholars of the time desired to set the seal of antique sanction, who shall determine? If Sanu and his warriors brought with them the worship of the sun, that would offer an interesting inference as to their origin. If the aid that they received from his light was suggested solely by the grateful homage that rice cultivators, thirteen centuries later, had learned to pay to his beneficence, then the oldest written records of Japan must be read as mere transcripts of the faiths and fashions of the era when they were compiled, not as genuine traditions transmitted from previous ages. But such distinctions have never been recognized by the Japanese. With them these annals of their race's beginnings have always commanded as inviolable credence as the Testaments of Christianity used to command in the Occident. From the lithographs that embellish modern bank notes the sun looks down on the semidivine conqueror, Jimmu, and receives his homage. From the grand cordon of an order instituted by his hundred and twenty-seventh successor depends the kite that guided him through mountain fastnesses, and on a thousand works of art the genius of the tortoise shows him the path across the ocean. If these picturesque elements were added by subsequent writers to the outlines of an ordinary armed invasion by foreign adventurers, the nation has received them and cherishes them to this day as articles of a sacred faith.

The annals here briefly summarized reveal three tides of more or less civilized immigrants and a race of semibarbarous autochthons. All the learned researches of modern archaeologists and ethnologists do not teach us much more. It is now known with tolerable certainty that the so-called autochthons were composed of two swarms of colonists, both coming from Siberia, though their advents were separated by a long interval.

The first, archaeologically indicated by pit dwellings and shell mounds still extant, were the Koro-pok-guru, or "cave men." They are believed to be represented to-day by the inhabitants of Saghalien, the Kuriles, and southern Kamschatka.

The second were the Ainu, a flat-faced, heavy-jawed, hirsute people, who completely drove out their predecessors and took possession of the land. The Ainu of that period had much in common with animals. They burrowed in the ground for shelter; they recognized no distinc-

tion of sex in apparel or of consanguinity in intercourse; they clad themselves in skins; they drank blood; they practiced cannibalism; they were insensible to benefits and perpetually resentful of injuries; they resorted to savagely cruel forms of punishment—severing the tendons of the legs, boiling the arms, slicing off the nose, etc.; they used stone implements, and, unceasingly resisting the civilized immigrants who subsequently reached the islands, they were driven northward by degrees, and finally pushed across the Tsugaru Strait into the island of Yezo. That long struggle, and the disasters and sufferings it entailed, radically changed the nature of the Ainu. They became timid, gentle, submissive folk; lost most of the faculties essential to survival in a racial contest, and dwindled to a mere remnant of semi-savages, incapable of progress, indifferent to improvement, and presenting a more and more vivid contrast to the energetic, intelligent, and ambitious Japanese.

But these Japanese—who were they originally? Whence did the three or more tides of immigration set which ultimately coalesced to form the race now standing at the head of Oriental peoples? Strangely varying answers to this question have been furnished. Kampfer persuaded himself that the primeval Japanese were a section of the builders of the Tower of Babel. Hyde-Clarke identified them with Turano-Africans who traveled eastward through Egypt, China, and Japan. Macleod recognized in them one of the lost tribes of Israel. Several writers have regarded them as Malayan colonists. Griffin was content to think that they are modern Ainu, and recent scholars incline to the belief that they belonged to the Tartar-Mongolian stock of Central Asia. Something of this diversity of view is due to the fact that the Japanese are not a pure race. They present several easily distinguishable types, notably the patrician and the plebeian. This is not a question of mere coarseness in contrast with refinement; of the degeneration due to toil and exposure as compared with the improvement produced by gentle living and mental culture. The representative of the Japanese plebs has a conspicuously dark skin, prominent cheek bones, a large mouth, a robust and heavily boned physique, a flat nose, full straight eyes, and a receding forehead. The aristocratic type is symmetrically and delicately built; his complexion varies from yellow to almost pure white; his eyes are narrow, set obliquely to the nose; the eyelids heavy; the eyebrows lofty; the mouth small; the face oval; the nose aquiline; the hand remarkably slender and supple.

Here are two radically distinct types. What is more, they have been distinguished by the Japanese themselves ever since any method of recording such distinctions existed. For from the time when he first began to paint pictures, the Japanese artist recognized and represented only one type of male and female beauty—namely, that distinguished in a marked, often an exaggerated, degree by the features

enumerated above as belonging to the patrician class. There has been no evolution in this matter. The painter had as clear a conception of his type ten centuries ago as he has to-day. Nothing seems more natural than the supposition that this higher type represents the finally dominant race of immigrants; the lower, their less civilized opponents.

The theory which seems to fit the facts best is that the Japanese are compounded of elements from Central and Southern Asia, and that they received their patrician type from the former, their plebeian from the latter. The Asiatic colonists arrived via Korea. But they were neither Koreans nor Chinese. That seems certain, though the evidence which proves it can not be detailed here. Chinese and Koreans came from time to time in later ages; came occasionally in great numbers, and were absorbed into the Japanese race, leaving on it some faint traces of the amalgamation. But the original colonists did not set out from either China or Korea. Their birthplace was somewhere in the north of Central Asia. As for the South-Asian immigrants, they were drifted to Japan by a strange current called the "Black Tide" (*Kuro-shiwo*), which sweeps northward from the Philippines, and bending thence toward the east, touches the promontory of Kii and Yamato before shaping its course permanently away from the main island of Japan. It is true that in the chronological order suggested by early history the southern colonists succeeded the northern and are supposed to have gained the mastery; whereas among the Japanese, as we now see them, the supremacy of the northern type appears to have been established for ages. That may be explained, however, by an easy hypothesis—namely, that although the onset of the impetuous southerns proved at first irresistible, they ultimately coalesced with the tribes they had conquered, and in the end the principle of natural selection replaced the vanquished on their proper plane of eminence. But this distinction, it must be observed, is one of outward form rather than of moral attributes. Neither history nor observation furnishes any reason for asserting that the so-called "aristocratic," or Mongoloid, cast of features accompanies a fuller endowment of either physical or mental qualities than the vulgar, or Malayan, cast. Numerically the patrician type constitutes only a small fraction of the nation, and seems to have been lacking in a majority of the country's past leaders, as it is certainly lacking in a majority of her present publicists, and even in the very creme de la creme of society. The male of the upper classes is not generally an attractive product of nature. He has neither commanding stature, refinement of features, nor weight of muscle. On the other hand, among the laboring populations, and especially among the seaside folk, numbers of men are found who, though below the average Anglo-Saxon or Teuton in bulk, are cast in a perfectly symmetrical

mold and suggest great possibilities of muscular effort and endurance. In short, though the aristocratic type has survived, and though its superior beauty is universally recognized, it has not impressed itself completely on the nation, and there is no difficulty in conceiving that its representatives went down before the first rush of the southern invaders, but subsequently, by tenacity of resistance and by fortitude under suffering, recovered from a shock which would have crushed a lower grade of humanity.

Histories that describe the manners and customs of a people have been rare in all ages. The compilers of Japan's first annals, in the eighth century, paid little attention to this part of their task. Were it necessary to rely on their narrative solely for a knowledge of the primeval Japanese, the student would be meagerly informed. But archæology comes to his assistance. It raises these men of old from their graves, and reveals many particulars of their civilization which could never have been divined from the written records alone.

The ancient Japanese—not the Koro-pok-guru or the Ainu, but the ancestors of the Japanese proper—buried their dead first in barrows and afterwards in dolmens. The barrow was merely a mound of earth heaped over the remains, after the manner of the Chinese. The dolmen was a stone chamber. It had walls constructed with blocks of stone, generally unhewn and rudely laid, but sometimes hewn and carefully fitted; its roof consisted of huge and ponderous slabs. It varied in form—sometimes taking the shape of a long gallery only, sometimes of a gallery and a chamber, and sometimes of a gallery and two chambers. Over it was built a mound of earth which occasionally assumed enormous dimensions, covering a space of 70 or 80 acres, rising to a height of as many feet, and requiring the labor of thousands of workmen. The builders of the barrows were in the bronze age of civilization, the constructors of the dolmens in the iron age. In the barrows are found weapons and implements of bronze and vessels of hand-made pottery; in the dolmens, weapons and implements of iron and vessels of wheel-turned pottery. There is an absolute line of division. No iron weapon nor any machine-made pottery occurs in a barrow, no bronze weapon nor any hand-made pottery in a dolmen. Are the barrow builders and the dolmen constructors to be regarded as distinct races or as men of the same race at different stages of its civilization? Barrow and dolmen bear common testimony to the fact that before the ancestors of the Japanese nation crossed the sea to their inland home they had already emerged from the stone age, for neither in barrow nor in dolmen have stone weapons or implements been found, though these abound in the shell heaps and kitchen middens that constitute the relics of the Koro-pok-guru and the Ainu. But, on the other hand, barrow and dolmen introduce their explorer to peoples who stood on different planes of industrial development.

The progress of civilization is always gradual. A nation does not pass, in one stride, from burial in rude tumuli to sepulture in highly specialized forms of stone vaults, nor yet from a bronze age to an iron. It is therefore evident that the evolution of dolmen from barrow did not take place within Japan. The dolmen constructor must have completely emerged from the bronze age and abandoned the fashion of barrow burial before he reached Japan. Otherwise search would certainly disclose some transitional form between the barrow and the dolmen, and some iron implements would occur in the barrows or bronze weapons in the dolmens. If, then, the barrow builder and the dolmen constructor were racially identical, it would seem to follow that the latter succeeded the former by a long interval in the order of immigration and brought with him a greatly improved type of civilization evolved in the country of his origin.

The reader will be naturally disposed to anticipate that the geographical distribution of the dolmens and the barrows furnishes some aid in solving this problem. But though the exceptional number found on the coasts opposite to Korea tends to support the theory that the stream of Mongoloid immigration came chiefly from the Korean Peninsula via the island of Tsushima, there is not any local differentiation of one kind of sepulture from the other, and, for the rest, the grouping of the dolmens supplies no information except that their builders occupied the tract of country from the shores opposite Korea on the west to Musashi and the south of Shimotsuke on the east, and did not penetrate to the extreme northeast or to the regions of mountain and forest in the interior.

Here another point suggests itself. If the fashion of the Japanese dolmen was introduced from abroad, evidences of its prototype should survive on the adjacent continent of Asia. If the numerous dolmens found on the coasts of Kiushiu and Isumo facing Korea are to be taken as indications that their constructors emigrated originally from the Korean Peninsula, then Korea also should contain similar dolmens, and if an ethnological connection existed between Japan and China in prehistoric days, China, too, should have dolmens. But no dolmens have hitherto been found in China, and the dolmens of Korea differ radically from those of Japan, being "merely cists with megalithic capstones" (Gowland). It has been shown, further, that dolmens similar to those of Japan are not to be found in any part of continental Asia eastward of the shores of the Caspian Sea, and that western Europe alone offers exactly analogous types. In short, from an ethnological point of view, the dolmens of Japan are as perplexing as the dolmens of Europe, and the prospect of solving the riddle seems to be equally remote in both cases. All that can be affirmed is that the dolmens offer strong corroborative testimony to the truth of the Japanese historical narrative which represents Jimmu as the leader of the last and

most highly civilized among the bands of colonists constituting the ancestors of the present Japanese race. Thus the "divine warrior," after having been temporarily erased from the tablets of history by the modern sceptic of the West, is projected upon them once more from the newly opened graves of the primeval Japanese. It is true that there is an arithmetical difficulty. It has been supposed that the dolmens do not date from a period more remote than the third century before Christ, whereas Jimmu's invasion is assigned to the seventh. But no great effort of imagination is required to effect a compromise between the uncertain chronology of the Japanese annals and the tentative estimates of modern archeologists.

Some of the burial customs revealed by these ancient tombs resemble the habits of the Scythians as described by Herodotus. The Japanese did not, it is true, lay the corpse of a chieftain between sheets of gold, nor did they inter his favorite wife with similar pomp in an adjoining chamber; but they did deposit with him his weapons, his ornaments, and the trappings of his war horse, and in remote times they followed the barbarous rule of burying alive, in the immediate vicinity of his sepulcher, his personal attendants, male and female, and probably also his steed. To the abrogation of that cruel rule is due much information about the garments worn in early epochs, for in the century immediately preceding the Christian era a kind-hearted emperor decided that clay figures should be substituted for human victims, and these figures, being modeled, however roughly, in the guise of the men and women of the time, tell what kind of costumes were worn and what was the manner of wearing them. Collecting all the available evidence, the story shapes itself into this:

Prior to the third, or perhaps the fourth century before the Christian era, when the dead were interred in barrows, not dolmens, the Japanese, though they stood on a plane considerably above the general level of Asiatic civilization, did not yet understand the forging of iron or the use of the potter's wheel. They were still in the bronze age, and their weapons—swords, halberds, and arrowheads—were made of that metal. Concerning the fashion of their garments not much is known, but they used for purpose of personal adornment, quaintly shaped objects of jasper, rock crystal, steatite, and other stones. Then, owing probably to the advent of a second wave of immigration from the continent, the civilization of the nation was suddenly raised, and the country passed at once from the bronze to the iron age, with a corresponding development of industrial capacity in other directions, and with a novel method of sepulture having no exact prototype except in western Europe. The newcomers seem to have been, not a race distinct from their predecessors, but a second outgrowth of colonists from the same parent stem. Where that stem had its roots there is no clear indication, but it is evident that, during the

interval between the first and the second migrations, the mother country had far excelled its colony in material civilization, so that, with the advent of the second band of wanderers, the condition of the Japanese underwent marked change. They laid aside their bronze weapons and began to use iron swords and spears, and iron-tipped arrows. A warrior carried one sword and, perhaps, a dagger. The sword had a blade which varied from $2\frac{1}{2}$ feet to over 3 feet in length. These were not the curved weapons with curiously modeled faces and wonderful trenchancy which became so celebrated in later times. Straight, one-edged swords, formidable enough, but considerably inferior to the admirable katana of medieval and modern eras, they were sheathed in wooden scabbards, having bands and hoops of copper, silver, or iron, by means of which the weapon was suspended from the girdle. The guards were of iron, copper, or bronze, often coated with gold, and always having holes cut in them to render them lighter. Wood was the material used for hilt as well as for scabbard, but generally in the former case and sometimes in the latter a thin sheet of copper with gold plating enveloped the wood. Double barbs characterized the arrowhead, and as these projected about 4 inches beyond the shaft, a bow of great strength must have been used, though of only medium length. Armor does not seem to have been generally worn, or to have served for covering any part of the body, except the head and the breast. It was of iron, and it took the shape of thin bands of metal, riveted together for casque and cuirass. Neither brassart, visor, nor greaves have been found in any dolmen, and though solerets of copper are among the objects exhumed, they appear to have been rather ornamental than defensive. As to shields, nothing is known. No trace of them has been found, and it seems a reasonable inference that they were not used. Horses evidently played an important part in the lives of the second batch of immigrants, for horse furniture constantly appears among the objects found in dolmens. The bit is almost identical with the common "snaffle" of the Occident. Made of iron, it has siderings or cheek pieces of the same metal, elaborately shaped and often sheeted with gilded copper. The saddle was of wood, peaked before and behind and braced with metal bands, and numerous ornaments of repoussé iron covered with sheets of gilt or silvered copper were attached to the trappings. Among these ornaments a peculiar form of bell is present, an oblate hollow sphere, having a long slit in its shell and containing a loose metal pellet. Stirrups are seldom found in the dolmens, and the rare specimens hitherto exhumed bear no resemblance to the large, heavy, shoe-shaped affairs of later ages, but are rather of the Occidental type.

The costume of these ancient Japanese had little in common with that of their modern descendants. They wore an upper garment of woven stuff fashioned after the manner of a loosely fitting tunic, and

confined at the waist by a girdle, and they had loose trousers reaching nearly to the feet. For ornaments they used necklaces of beads or of rings—silver, stone, or glass; finger rings, sometimes of silver or gold, sometimes of copper, bronze, or iron, plated with one of the precious metals; ring-shaped buttons; metal armlets; bands or plates of gilt copper, which were attached to the tunic; earrings of gold, and tiaras. Not one item in this catalogue, the tiara excepted, appears among the garments or personal ornaments of the Japanese since their history and habits began to be known to the outer world. No nation has undergone a more radical change of taste in the matter of habiliments and adornments. The earring, the necklace, the finger ring, the bracelet, and the band or plate of metal attached to the tunic—all these passed completely out of vogue so long ago that, without the evidence of the contents of the dolmen, it would be impossible to conceive the existence of such things in Japan. One of the most noteworthy features of the people's habits in medieval or modern times is that, with the solitary exception of pins and fillets for the hair, they eschew every class of personal ornament. Yet the dolmens indicate that personal adornments were abundantly, if not profusely, employed by the ancestors of these same Japanese in prehistoric days. Indeed, the only features common to the fashions of the Japanese as they are now known and the Japanese as their sepulchers reveal them are the rich decoration of the sword hilt and scabbard and of the war horse's trappings.

As to the food of these early people, it seems to have consisted of fish, flesh, and cereals. They used wine of some kind, though of its nature there is no knowledge, and their household utensils were of pottery, graceful in outline, but unglazed and archaically decorated. Whether or not they possessed cattle there is no evidence, nor yet is it known what means they employed to produce fire, though the fire drill appears to be the most probable.

That they believed in a future state is evident, since they buried with the dead whatever implements and weapons might be necessary in the life beyond the grave; that ancestral worship constituted an important part of their religious cult is proved by the offerings periodically made at the tombs of the deceased; and that idolatry was not practised or superstition largely prevalent may be deduced from the complete absence of charms or amulets among the remains found in their sepulchers.

THE KOREAN LANGUAGE.[a]

By Homer B. Hulbert.

The Korean language belongs to that widely disseminated family to which the term Turanian has sometimes been applied. This term is sufficiently indefinite to match the subject, for scholarship has not yet determined with any degree of exactitude the limits of its dispersion. At its widest reach it includes Turkish, Hungarian, Basque, Lappish, Finnish, Ouigour, Ostiak, Samoiyed, Mordwin, Manchu, Mongol (and other Tartar and Siberian dialects), Japanese, Korean, Tamil, Telugu, Canarese, Malayalam (and the other Dravidian dialects), Malay and a great number of the Polynesian and Australasian dialects reaching north along the coast of Asia through the Philippine Islands and Formosa and south and east into New Guinea, New Hebrides, and Australia.

The main point which differentiates this whole family of languages from the Aryan and Semitic stocks is the agglutinative principle, whereby declension and conjugation are effected by the addition of positions and suffixes and not by a modification of the stem. In all these different languages the stem of a word remains as a rule intact through every form of grammatical manipulation. That Korean belongs to this family of languages is seen in its strictly agglutinative character. There has been absolutely no deviation from this principle. There are no exceptions. Any typical Korean verb can be conjugated through its one thousand different forms without finding the least change in the stem. A comparison of Korean with Manchu discloses at once a family likeness and at the same time a comparison of Korean with any one of the Dravidian dialects discloses a still closer kinship. It is an interesting fact that not one of the Chinese dialects possesses any of the distinctive features of this Turanian family. There is more similarity between Chinese and English than between Chinese and any one of the Turanian languages. In other words, China has been even more thoroughly isolated linguistically than she has socially; and the

[a] Reprinted from The Korea Review, Seoul, Korea, Homer B. Hulbert, editor, Vol. I, 1901, pp. 433–440.

evidence goes to prove that at some period enormously remote, after the original Chinese had effected an entrance to the mighty amphitheater between the Central Asian mountains on the one hand and the Pacific on the other, they were surrounded by a subsequent race who impinged upon them at every point and conquered them not once or twice, but who never succeeded in leaving a single trace upon her unique and primitive language. This surrounding family was the Turanian, and Korean forms one link in the chain. Korean bears almost precisely the same relation to Chinese that English does to Latin. English has retained its own distinct grammatical structure while drawing an immense number of words from the romance dialects for the purposes of embellishment and precision. The same holds true of Korean. She has never surrendered a single point to Chinese grammar, and yet has borrowed eagerly from the Chinese glossary as convenience or necessity has required. Chinese is the Latin of the Far East, for just as Rome, through her higher civilization, lent thousands of words to the semisavages hovering along her borders, so China has furnished all the surrounding peoples with their scientific, legal, philosophical, and religious terminology. The development of Chinese grammar was early checked by the influence of the ideograph, and so she has never had anything to lend her neighbors in the way of grammatical inflection.

The grammars of Korea and Japan are practically identical; and yet, strange to say, with the exception of the words they have both borrowed from China their glossaries are marvelously dissimilar. This forms one of the most obscure philological problems of the Far East. The identity in grammatical structure, however, stamps them as sister languages.

The study of Korean grammar is rendered interesting by the fact that in the surrounding of China by Turanian peoples, Korea was the place where the two surrounding branches met and completed the circuit. Northern Korea was settled from the north by Turanian people. Southern Korea was settled from the south by Turanian people. It was not until 193 B. C. that each became definitely aware of the presence of the other. At first they refused to acknowledge the relationship, but the fact that when in 690 A. D. the southern kingdom of Sil-la assumed control of the whole peninsula there remained no such line of social cleavage as that which obtained between the English and the Norman after 1066, shows that an intrinsic similarity of language and of racial aptitude quickly closed the breach and made Korea the unit that she is to-day.

Korean is an agglutinative, polysyllabic language whose development is marvelously complete and at the same time marvelously symmetrical. We find no such long list of exceptions as that which entangles in its web the student of the Indo-European languages. In

Korean as in most of the Turanian languages the idea of gender is very imperfectly developed, which argues perhaps a lack of imagination. The ideas of person and number are largely left to the context for determination, but in the matter of logical sequence the Korean verb is carried to the extreme of development.

The Korean's keen sense of social distinctions has given rise to a complete system of honorifics, whose proper use is essential to a rational use of the language. And yet numerous as these may be their use is so regulated by unwritten law and there are so few exceptions that they are far easier to master than the personal terminations of Indo-European verbs. The grammatical superiority of Korean over many of the western languages is that while in the latter differences of gender, number, and person, which would usually be perfectly clear from the context, are carefully noted, in the Korean these are left to the speaker's and the hearer's perspicacity and attention is concentrated upon a terse and luminous collocation of ideas; which is often secured in the west only by a tedious circumlocution.

The genius of the language has led the Korean to express every possible verbal relation by a separate modal form. The extent to which this has been carried can be shown only by illustration. Besides having simple forms to express the different tenses and the different modes, indicative, potential, conditional, imperative, infinitive, it has simple forms to express all those more delicate verbal relations which in English require a circumlocution or the use of various adverbs. For instance, the Korean has a special mode to express necessity, contingency, surprise, reproof, antithesis, conjunction, temporal sequence, logical sequence, interruption, duration of time, limit of time, acquiescence, expostulation, interrogation, promise, exhortation, imprecation, desire, doubt, hypothesis, satisfaction, propriety, concession, intention, decision, probability, possibility, prohibition, simultaneity, continuity, repetition, infrequency, hearsay, agency, contempt, ability, and many other relations. Each one of these ideas can be expressed in connection with any active verb by the simple addition of one or more inseparable suffixes. By far the greater number of these suffixes are monosyllables.

To illustrate the delicate shades of thought that can be expressed by the addition of a suffix, let us take the English expression "I was going along the road, when suddenly ——!" This, without anything more, implies that the act of going was interrupted by some unforeseen circumstance. This would be expressed in Korean by three little words nă-ga="I," kil-e="along the road," ka-ta-ga="was going, when suddenly ——." The stem of the verb is ka and the sudden interruption of the action is expressed by the ending ta-ga; and, what is more, this ending has absolutely no other use. It is reserved

solely for the purpose of expressing succinctly this shade of thought. The little word kal-ka of which ka is the stem, meaning "go," contains all the meaning that we put into the words "I wonder now whether he will really go or not." Someone asks you if you are going, and all you need to say is "ka-na" to express the complete idea of "What in the world would I be going for? Absurd!"

Another thing which differentiates Korean from the languages of the west is the wide difference between book language and spoken language. Many of the grammatical forms are the same in both, but besides these there is a full set of grammatical endings used in books only while at the same time there are many endings in the vernacular that could never be put in print. The result is very unfortunate, for of necessity no conversation can be written down verbatim. It must all be changed into indirect discourse, and the vernacular endings must largely be changed to the book endings. This must not be charged up against the Korean, for it came in with the Chinese, and is but one of the thousand ways in which their overpowering influence, in spite of all it has done for Korea, has stunted her intellectual development. We would not imply that these literary endings are borrowed from the Chinese, for such is rarely the case; but as Korea has little literature except such as has grown up beneath the wing of China, it was inevitable that certain endings would be reserved for the formal writing of books while others were considered good enough only to be bandied from mouth to mouth. It is of course impossible to say what Korea would have accomplished had she been given a free rein to evolve a literature for herself, but we can not doubt that it would have been infinitely more spontaneous and lifelike than that which now obtains.

From a linguistic standpoint the Koreans are probably far more homogeneous than any portion of the Chinese people lying between equal extremes of latitude. There is in Korea no such thing as dialects. There are different "brogues" in the peninsula, and the Seoul man can generally tell the province from which a countryman comes by his speech. But it would be wide of the truth to assert that Koreans from different parts of the country can not easily understand each other. To be sure there are some few words peculiar to individual provinces, but these are mutually known just as the four words "guess," "reckon," "allow," and "calculate," while peculiar to certain definite sections of the United States, are universally understood.

A word in conclusion must be said regarding the laws of Korean euphony. No people have followed more implicitly nature's law in the matter of euphony. It has not been done in the careless manner that changed the magnificent name Caesar Augustus to the slovenly Saragossa, but the incomparable law of the convertibility of surds and sonants which is characteristic of the Turanian languages is

worked out to its ultimate end in Korean. The nice adjustment of the organs of speech whereby conflicting sounds are so modified as to blend harmoniously is one of the unconscious Korean arts. Who told them to change the labial surd "p" of Ap-nok to its corresponding labial nasal "m" before the following nasal, which leaves the euphonious word amnok; or to change the lingual nasal "n" of in-pi to its corresponding labial nasal "m" before the labial surd "p," giving the phonetically correct impi? The evidence goes to show that the euphonic tendency in Korea has not broken down the vocabulary as is sometimes the case. Prof. Max Müller speaks of the law of phonetic decay; and rightly so, when the romance languages are under discussion, but in Korea this law would better be called one of phonetic adjustment. When rough stones are put together to form a roadbed, if they are of good quality they work down together, get their corners knocked off, and form a solid and durable surface; but if the stone is poor the pieces will mutually pulverize each other and the road will be worthless. The former of these processes represents phonetic adjustment while the latter represents phonetic decay. The comparative virility of French and Italian speech, in spite of phonetic decay, is brought about by the compensating law of dialectic regeneration, but the Portuguese language, for instance, shows no such vitality. Cross-breeding is as necessary to the vitality of a language as grafting is to the production of good fruit.

Another feature which specially characterizes Korean speech is the great number of mimetic words, or, as they are sometimes called, onomatopoeia. As Korean colors are drawn directly from nature, so a great number of its words are phonetic descriptions. And the reason why such primitive nature-words are still found intact in a language so highly developed as the Korean is because the principle of reduplication, common in all the Turanian languages, is carried to the extreme in Korean. A reduplicated mimetic word carries on its very face its mimetic quality, and consequently the very conspicuousness of this quality has prevented change. Its very raison d'etre being its phonetic description of the object or the act, a change in the sound is rendered very unlikely. For instance, the Korean word t'ŭl-bŭk t'ŭl bŭk means precisely what an English or an American boy would express by the word "ker-splash!" which is itself keenly mimetic. In Korean the syllable t'ŭl, and in English the "ker" represents the sharp spat with which a heavy body strikes the surface of the water, and the Korean bŭk represents the heavy sound which follows when the water comes together over the object. In English the splash represents rather the spray thrown up by the impact of the water. It will readily be seen that the reduplication of the t'ŭl-bŭk would tend to secure permanency in the pronunciation. Mimetic words in English have so often lost their evident mimetic quality; as

in the word "sword," which was originally pronounced with the "w," in imitation of the sound of the weapon sweeping through the air, but having lost the w sound it now has no phonetic significance. One hardly needs a dictionary to learn the meaning of Korean onomatopoeia. What could "jing-geu-rŭng jăng-geu-rŭng" mean but the jingle-jangle of bells or of the steel rings on the horses' bridles? So again mulsin mulsin means soft to the touch, based on the same idea as our word "mellow" in which the softest sounds of human speech, "m" and "l," are used. On the other hand bak-bak means hard, stiff, unyielding, after the analogy of our word "brittle," which is doubtless mimetic. The Korean word whose stem is ch'i means to strike or hit, and is the phonetic equivalent of our vulgar word "chug," whose mimetic origin can not be doubted. One must conclude that the prevalence of mimetic words in all languages forms a serious obstacle to the study of philology, for attempts on the part of widely separated people to produce a phonetic description of an object, quality, or act that is common to them both is most likely to result in similar sounds. And these, later, form dangerous traps into which the eager and unwary philologue is prone to fall.

It may be asked whether the Korean language is adapted to public speaking. We would answer that it is eminently so. For, in the first place, it is a sonorous, vocal language. The Koreans say that in any syllable the vowel is the "mother" and the consonant is the "child," showing that they have grasped the essential idea that vowel sounds form the basis of human speech. The sibilant element is much less conspicuous in Korean than in Japanese and one needs only to hear a public speech in Japanese and one in Korean to discover the vast advantage which Korean enjoys. Then again, the almost total lack of accent in Japanese words is a serious drawback from the point of view of oratory. So far as we can see there is nothing in Korean speech that makes it less adapted to oratory than English or any other western tongue. In common with the language of Cicero and Demosthenes, Korean is composed of periodic sentences, by which we mean that each sentence reaches its climax in the verb, which comes at the end; and there are no weakening addenda, such as often make the English sentence an anticlimax. In this respect the Korean surpasses English as a medium for public speaking.

THE REPUBLIC OF PANAMA.[a]

By Prof. Wm. H. Burr,
Of the Isthmian Canal Commission.

The youngest of the American republics has almost the oldest history. The Caribbean coast line of Colombia and of Panama was one of the earliest localities visited by the old Spanish navigators. One of them, Alonzo de Ojeda, visited a number of places along this coast in 1499 and 1501, while Columbus visited Porto Bello, 25 miles northeast of Colon, and other places in 1502, during his last voyage. From those dates onward all this portion of the Spanish main was constantly visited, explored, and apportioned among Spanish officials. Many expeditions of discovery were made inland, until all that northwesterly portion of South America which has so long been known as Venezuela, Colombia, and Ecuador was completely explored and a fair knowledge of its resources, mineral and otherwise, obtained.

One of the most important incidents in these exploring expeditions occurred when Vasco Nunez de Balboa, governor of the province in Darien, first set out southward from his capital, Santa Maria de la Antigua, prompted by what the Indians had told him, and from an elevation on the divide north of the Gulf of San Miguel, discovered the Pacific Ocean on the 25th day of September, 1513. Many of the earliest historical events of the Republic of Panama are associated with this intrepid explorer. He was on the Isthmus but a short period, but his restless energy was ever prompting him to new enterprises of exploration and aggrandizement of territory for his home government. His remarkable career was cut short in 1517 by his execution at Acla, on the Caribbean shore of the Gulf of Darien, by a jealous governor of the province, who feared that Balboa's fruitful enterprises might give him sufficient éclat to make him the head of the new Spanish territory in place of himself.

The Spanish discoverers found all this country, like others of South and Central America, peopled with large numbers of Indians.

The territory constituting the present Republic of Panama, as well as the northwesterly portion and west coast of South America, was carefully scoured in search of the precious metals of which fabulous

[a] Reprinted by permission from The National Geographic Magazine, Vol. xv, No. 2, February, 1904.

stories were related by the natives, many of which were justified by subsequent results. Balboa himself visited the Pearl Islands in the Bay of Panama. These operations of the early Spaniards involved frequent crossing of the Isthmus, and even before the death of Balboa it became evident that the most practicable line of transportation was that which is now known as the Panama route.

Many attempts were made to find other practicable routes across the Isthmus between the Atrato River, emptying into the Gulf of Darien, and the Chagres River, emptying into the Caribbean Sea 8 miles west of Colon, but the advantages of the Panama route were promptly recognized by the Spaniards.

A territory, consisting largely of the present Panama, Colombia, and Venezuela, was formed into the province of Tierra-firma. It was the governor of this province, Pedro Arias de Avila, who, to strengthen his authority, brought charges against Balboa, and after a form of trial executed him at Acla. By the middle of the sixteenth century large numbers of Spaniards had migrated to this country and created flourishing centers of trade. About this time, in order to secure a more suitable government for his colony, the Spanish emperor created the presidency of New Granada, which was subsequently raised to the rank of a viceroyalty in 1718, then including not only Colombia and Venezuela but Ecuador also. The territory of the Isthmus formed the northwestern arm of this Spanish appanage.

Like that of most Spanish colonies, the government of the country was corrupt, being administered largely for the benefit of the favored few in authority; but on the whole the country flourished, the population increased, and trade extended along the lines of production of the country.

THE REVOLUTION AGAINST SPANISH AUTHORITY.

The course of affairs in the viceroyalty continued without much change until 1811. Many features of the Spanish rule had long borne heavily upon the people and aroused such feeling that at last they broke out into an insurrection against the home government. A continuous war against the Spanish forces sent to put down the insurrection continued until 1824, when Spanish authority disappeared. Meantime the Venezuelan patriot, Simon Bolivar, born in the city of Caracas in 1783, made his way into prominence in national affairs, and in 1819 completed a union of the three divisions of the country into the first Republic of Colombia. This republic was short lived. Venezuela withdrew in 1829 and Ecuador in 1830. The creation of the Republic of New Granada followed in 1831, but its constitution was not formed until 1832. Under it the territory was divided into eighteen provinces. The president of the new republic held office four years. The course of affairs was much disturbed, and a civil war broke out after one or

two presidential terms and did not close until 1841. In 1840 the province of Cartagena seceded from the new republic, and immediately thereafter the neighboring provinces of Panama and Veragua took the same step. This was the first period of independence of the Isthmus of Panama. The revolting States were soon reunited under a constitution reformed in 1843. The Republic of New Granada enjoyed little tranquillity, being subject to domestic disturbances of greater or less magnitude almost continuously, but various measures signifying general advancement in civilization were adopted from time to time. Among those was one by which slavery was entirely abolished in 1852.

An important alteration of the constitution took place in 1853, under which the provinces were merely federated into the Republic, each being granted the right to assume its independence at any time. This right under the constitution was asserted by Antioquia and Panama in 1856 and 1857, this being the second independence of the Province of Panama. Stormy times followed these national upheavals, and the independence of the provinces was not long undisturbed. A congress at Bogota established a republic under the name of the United States of Colombia in 1861, adopting a new federal constitution for the purpose of including all the territory hitherto held by the Republic of Colombia, including the Isthmus of Panama. The opposite party, however, victorious in the western portion of the country, declined to acknowledge the authority at Bogota. Internal disturbances of all degrees, including the assassination of leaders and bloody battles, constituted the programme until 1862, when the opposing parties came to terms to a sufficient extent to permit the appointment of a provincial government and the drawing up of a constitution. At this time another attempt, not successful, was made to reestablish the former Republic of the three countries—Venezuela, Colombia, and Ecuador—but under the constitution adopted May 8, 1863, the Republic of Colombia was erected, and it has endured to the present time. Insurrections and internal disorganizations prevailed for a number of years, and the history of the Republic has been accentuated by frequent revolutions, many of which have taken place in Panama.

EXTENT OF THE PRESENT REPUBLIC.

This brings us to the consideration of the Republic of Panama as it now stands, having declared its independence on November 3, 1903. The Republic of Panama is identical in territorial limits with the Department of Panama of the Republic of Colombia. This Department extended from Costa Rica on the west to a line drawn first nearly due south from Cape Tiburon at the southern limit of the Gulf of Darien, then southwesterly to a point on the Pacific coast a short distance southeast of Punta Cocalito. This last or eastern limit of the

Department of Panama is almost entirely along the divide between the Atrato River and the watershed draining into the Gulf of San Miguel.

The Republic of Panama lies between the parallels of 7° 15′ and 9° north latitude, and also between 77° 15′ and 82° 30′ longitude west from Greenwich. Approximately speaking, therefore, its extreme length east and west is about 350 miles, and its extreme width north and south 120 miles. Its population is not well determined, but it probably does not exceed 300,000. This population is largely composed of people of Spanish descent, but there are also large numbers of negroes, who have come chiefly from Jamaica during the constructing work conducted by the old Panama Company. A few Chinamen have also found their way to the Isthmus and become permanent residents. The native Indians are also occasionally seen on the zone of population between Panama and Colon. These races have been mingled in all conceivable proportions, so that the features or racial characteristics of one or more, or even all of these various nationalities, may be traced in the face of a single individual. Some of the old Spanish families have still retained the purity of their blood and are among the prominent people of the Isthmus. Its entire area is about 31,600 square miles, or about the area of the State of Indiana.

The Cordillera forming the main mountain ridge extending from South to North America and constituting the continental divide runs through the entire length of the Republic of Panama, in the eastern portion the divide being much nearer the Caribbean Sea than the Pacific Ocean, while in the western portion its location is more nearly central. The low notch or saddle in the Cordillera near the city of Panama, with a summit elevation about 300 feet above sea level, the lowest throughout the Central American Isthmus except at Nicaragua, affords the railroad location built upon nearly fifty years ago and the recommended route for the Isthmian ship canal.

Not less than one-half of the entire territory of the Republic is mountainous and covered with luxuriant tropical vegetation, including heavy forest trees, some of which are among the highly valuable woods. These forests are practically trackless. Tribes of Indians, not in large numbers, live along the Caribbean coast between Panama and Darien, and also on the southern slopes. Some of these Indians preserve jealously their isolation, and have never acknowledged the sovereignty of any government.

PANAMA RAILROAD.

The most prominent feature of the Republic of Panama is the Panama Railroad and the partially constructed canal, with the adjacent strip of territory, including the cities and towns, with their aggregated business or industrial centers, along the line from Colon to Panama.

This railroad, a single-track line of 5 feet gauge, was built nearly fifty years ago. It is but 49 miles long, and it is conducted practically

as an American railroad corporation, although it is owned by the new Panama Canal Company. The principal offices of the company are in the city of New York. This company does not confine itself wholly to railroad business, but owns and conducts the line of steamers running between the ports of New York and Colon under the name of the Panama Railroad-Steamship Company.

The railroad forms a line of land transportation to which converges marine commerce from many widely separated ports of the world. On the Pacific side steamship lines plying up and down the west coast of South America, and the Pacific mail steamships touching along the North and Central America coast from San Francisco southward, together with other ships approaching from the Pacific Ocean, have made Panama their terminal port for many years. The port of Colon has an equally extensive ocean shipping business, with not less than nine or ten steamship lines from Spain, France, England, Germany, Italy, and the United States, making it either a terminal port or port of call. In addition to these ocean steamship lines there is a little coasting trade of a local character on both sides of the Isthmus carried on in small sailing vessels.

The Panama Railroad has always been a prominent transportation line, along which currents of commerce and streams of passenger traffic, fed by the steamship lines on the two oceans, have continuously flowed. Latterly a considerable banana trade has also sprung up along the railroad line.

RELATION OF THE ISTHMUS TO THE REST OF THE WORLD.

The location of the Isthmus is markedly central to that portion of the through commerce of the world which would be served by the Panama Canal. It is practically a halfway station between the ports of eastern Asia, Australia, and the islands between and the ports of Europe. It is believed that the opening of the canal will create a highly stimulating influence upon the trade between the west coast of South America and the ports of the United States—a business which has hitherto been developed chiefly with foreign ports. The geographical relation of the Republic of Panama to some of the principal ports of the world is shown by the following statement of the distances in nautical miles to be sailed by steam vessels on the respective trips indicated:

	Miles.
From Panama to San Francisco	3,277
From Panama to Honolulu	4,665
From Panama to Yokohama	8,065
From Panama to Shanghai	8,985
From Colon to New York	1,981
From Colon to Liverpool	4,720
From Colon to New Orleans	1,380

RESOURCES OF THE REPUBLIC.

The mineral resources of the Republic of Panama are practically undeveloped, although it is known that there are considerable deposits of coal of fair quality—perhaps of excellent quality—not far from the railroad and Canal Zone. The precious metals are found in small quantities at many points, with indications of greater value; but these resources, like many others of the new Republic, are in such an undeveloped stage that no definite statement can be made as to their potential value.

The agricultural resources of the country are greater than ordinarily supposed. There is excellent grazing land near Colon, along the Panama Railroad, and within a few miles of the city of Panama. Farther west, in the Chiriqui district, and on the Pacific side of that portion of the Isthmus, there are extensive stretches of country well adapted to agricultural purposes, both for grazing and for the raising of all those tropical products which grow in such luxuriance throughout the fertile portions of Central America and the Isthmus. Fine grades of stock in substantial numbers are already found on some portions of the Isthmus, and dairy farming is already conducted in the vicinity of Panama.

Large stretches of native forests of valuable timber, such as mahogany, both light and dark, and other similar woods are found throughout the Republic, but are yet practically undeveloped. Such valuable tropical products as cacao, bananas of all kinds, sugar cane, indigo, cotton, tobacco, vanilla, corn, rice, and other similar products grow in abundance, and conditions of systematic industry only are needed to develop them into sources of great wealth to the country. Under the encouraging influences of a stable government, where life and property are respected, the national resources of the Republic of Panama will be productive of an amount of wealth which, if stated in a quantitative way, would now be incredible, in view of the crude and depressed conditions of industry which have prevailed from the beginning of its history to the present time.

COMMUNICATION.

There are practically no roads found in the Republic except those of a crude and ill-kept kind near to the cities or towns along the line of the Panama Railroad Company between Colon and Panama. The only marked exception to this statement is the old so-called Royal road built between Cruces, on the upper Chagres, to Panama, a distance of about 17 miles. This old road, formerly a crudely paved way, was traveled by passengers crossing the Isthmus before the construction of the Panama Railroad. This traffic found its way up the Chagres River to the small native town of Cruces, now containing a few scores

of people, and then passed overland from that point either on foot or horseback, or by such crude vehicles as the country afforded, to Panama. It was by this route that many people went to California during the gold excitement of 1849 and the years immediately following. This road has been abandoned for many years, as has the ancient road from Portobello to Panama.

The greater portion of the territory of the Republic is of small elevation, with many large marshes along the seacoast. Even the mountainous portions east and southeast of the railroad, forming the Darien country, are not high, probably in no case exceeding an elevation of 2,800 feet. The arable land on either side of the Isthmus is mostly ground of low elevation.

CLIMATE.

The climate of the Isthmus is thoroughly tropical in character, but it is by no means entitled to the bad name which is so frequently given to it. In speaking of this climate, all business and social activity in the Republic of Panama is so centered in the vicinity of the railroad line, which is also practically the proposed canal route, that observations as to climatic or other conditions apply strictly to this vicinity, although they are practically the same for other parts of the Republic.

At Panama the Isthmus is scarcely more than 40 miles wide. The proximity of the two oceans necessarily affects the climate in a marked manner. The continental divide at this location is low, rising to an elevation but little more than 300 feet above mean sea level. Winds therefore blow across the entire Isthmus almost unobstructed. Under the tropical sun the evaporation from the two oceans is rapid, and the consequence is an atmosphere highly charged with aqueous vapor at nearly all times. The high temperature of the tropical climate is therefore accentuated with great humidity, which is enervating to a marked degree to those who have been bred in a temperate climate.

The temperature at Colon, on the Caribbean side of the Isthmus, not often rises above 90° F., although it occasionally reaches 98° or even a little higher, as in December, 1885 (98.2°), and January and March, 1886 (98.2°), the latter year being an unusually hot one. The mean of the maximum monthly temperature that year was 95.2° F. The usual maximum monthly temperature ranges from about 85° F. to about 91° or 92° F. The minimum monthly temperature usually ranges from about 60° F. to about 75° F., the mean minimum monthly temperature being but little under 70° F. The mean temperature throughout the year is not far from 80° F. The interior points of the Isthmus, such as Gamboa and Obispo, about halfway across the Isthmus on the railroad line, generally experience maximum temperatures perhaps 2 or 3 degrees higher than at Colon, and minimum temperatures perhaps 3 or 4 degrees lower than at that point. On the Pacific

side the temperature may run a degree or two higher than at Colon. For all ordinary purposes it may be stated that there is no sensible difference in temperature on the two sides of the Isthmus, nor in other climatic conditions except the rainfall, which differs sensibly. On the high ground at Culebra, where the canal and railroad lines cut the continental divide, and where the elevation is from 200 to 300 feet above sea level, the air is cooler and dryer than at either seacoast. These figures show that the ruling temperatures on the Isthmus are not so high as those shown by the hottest weather of a New York or Washington summer; but the temperatures, such as they are on the Isthmus, continue without material abatement.

The low latitude of the Isthmus of Panama, the farthest point north lying in latitude 9°, brings the sun at the zenith twice during the year, once at noon on April 13 on its journey northward, and the second time at noon on August 29, on its return southward toward the winter solstice. At the summer solstice its elevation above the north horizon is 75° 41′ and 57° 24′ above the south horizon at the winter solstice. These conditions introduce an approach to uniformity in the temperature of the varying seasons, as they also produce opposite prevailing winds in different portions of the year. As the direct rays of the sun tend to cause the hot air to rise vertically under it during those portions of the year when the sun is north of the zenith, the prevailing winds are southerly or southwesterly, but when it is south of the zenith the same causes make the prevailing winds from north or northeasterly. It is in this portion of the year when at rare intervals the northers blow into the harbor of Colon with such severity as to require ships found in it to put to sea for their safety.

The year on the Isthmus is divided into the dry season and the wet season. The dry season covers the four months of January, February, March, and April, during which little or no rain falls. The wet season is composed of the remaining eight months of the year, the wettest portions being usually in May and in October. The rainfall on the Caribbean side—i. e., at Colon—is considerably greater than either in the interior or on the Pacific side, its annual amount usually ranging from about 85 to nearly 155 inches, with an average of about 125 to 130 inches. In the interior, as at Gamboa or Bas Obispo, the annual precipitation varies ordinarily from about 75 to nearly 140 inches, with an average of 90 to 95 inches. The total precipitation at Panama, however, may vary from about 45 to about 85 inches per annum, with an average of about 66 to 67 inches. As the average annual precipitation in New York or Washington may vary approximately from 40 to 50 inches, it is seen that the wet season in the Republic of Panama exhibits relatively high rainfall, although not more than about one-half of that which occurs at Greytown, in Nicaragua.

During the wet months there are some phenomenal downpours, with the effect of turning rivers into torrents, and this is particularly the case with the Chagres River, the principal river of the Republic, which empties into the Caribbean Sea about 8 miles west of Colon. Passing up this river from its mouth, its general course lies southeast for a distance of nearly 30 miles to Obispo. Still passing upstream, its course at this point turns sharply to the northeast. From Obispo for a distance of about 23 miles downstream the course of the Panama Railroad and the line of the proposed canal follow the Chagres River to the lowlands adjoining the Caribbean coast. In the other direction, however, both the railroad and the canal leave the river at Obispo and cut through the continental divide toward Panama, the Panama end of the canal being about 20 miles from Obispo.

VARIOUS PROJECTS FOR A SHIP CANAL.

At the present time the greatest interest centering on the Republic of Panama, aside from the remarkable unanimity with which the people of the Isthmus as a unit declared and secured their independence through a single, effective, but bloodless effort, is that which attaches to the proposed ship canal connecting the two oceans practically along the line of the Panama Railroad. The project of an isthmian ship canal is almost as old as the discovery of the Isthmus, for it is nearly 400 years ago that the Spaniards themselves seriously discussed this enterprise. As early as 1520 the Spanish monarch, Charles V, directed a survey to be made for the purpose of determining the feasibility of an isthmian ship canal. From that time until this the project of a ship canal across the Isthmus has been actively discussed, although as a result of that early survey the Spanish governor declared "that such a work was impracticable, and that no king, however powerful he might be, was capable of forming a junction of the two seas, or of furnishing the means of carrying out such an undertaking." The followers of the Spanish governor were less easily discourged than he.

The ship-canal enterprise gathered advocates from one century to another, until, during the nineteenth century and the first years of the twentieth, many careful surveys of possible routes across the Isthmus were made. The principal of those lying in the Republic of Panama, beginning with the most easterly, are the Caledonia route, the San Blas route, and the Panama route. The Caledonia route has at times attracted much attention on account of the highly colored but absolutely false accounts rendered of it by one or two early explorers. The northern extremity of this route, at Caledonia Bay, is about 165 miles east of Colon, and crosses the Isthmus in the main in a southwesterly direction. The surveys of the Isthmian Canal Commission showed that the elevation of the divide at this point and the heavy

work to be done along its line were far too great to permit its feasibility being considered in comparison with that of the Panama route. The San Blas route, the Caribbean end of which is on the Gulf of San Blas, is about 60 miles east of Colon. This route has the distinguishing characteristic of being located on probably the shortest line between the tide waters of the two oceans on the Isthmus, this distance being scarcely 30 miles. The short length of this line has secured for it a number of earnest advocates. It also was subject to survey by the engineering parties of the Isthmian Commission. The elevation of the divide at this crossing is so great as to necessitate the consideration of a ship tunnel from 5 to 7 miles long, the canal being planned as a sea-level waterway. The great cost of a canal on this line and the hazards attending such a construction as a ship tunnel rendered this route, like the Caledonia line, neither practicable nor feasible, compared with the Panama route.

Many surveys and examinations have been made at different crossings of the Central American isthmus between Tehuantepec, in Mexico, and the eastern limit of the Republic of Panama. As earnest and as enthusiastic as the supporters of other routes have been, the most complete and exact surveys and estimates have shown that the Panama route embodies the greatest number of advantages of any line ever considered for a ship canal between the two oceans. It is a tribute to the sagacity and good judgment of the old Spanish explorers that they also settled upon practically this route as the most feasible and practicable for the same purpose.

The proposed Panama line, favorably reported upon by the Isthmian Canal Commission and now adopted as the basis of the treaty being negotiated between the United States and the Republic of Panama, begins at Colon and extends in a southeasterly direction to a point on the bay of Panama near the city of that name, and has a total length of 49.07 miles between the six-fathom curves in the two oceans. At the present time the city of Colon has a population of probably about 3,000 people, while the city of Panama has a population of perhaps 25,000 people. The population scattered along the line of the railroad may add 10,000 to 15,000 more, making a total of perhaps 40,000 to 45,000 people in the 10-mile strip of territory between the two oceans within which the railroad is found and the canal will be built.

THE PLAN OF DE LESSEPS.

This canal route is that which was adopted at the International Scientific Congress convened in Paris in May, 1879, under the auspices of Ferdinand de Lesseps, the concession for the canal having been obtained from the Republic of Colombia in the preceding year by Lieut. L. N. B. Wyse, a French naval officer. This congress not only selected the Panama route, but also decided that the waterway to be

FIG. 1.—ONE OF THE HOSPITAL BUILDINGS ON THE HILL BACK OF PANAMA.

FIG. 2.—LOW TIDE IN THE HARBOR OF PANAMA.

The range of tide at Panama is 20 feet, and at Colon only 1 foot.

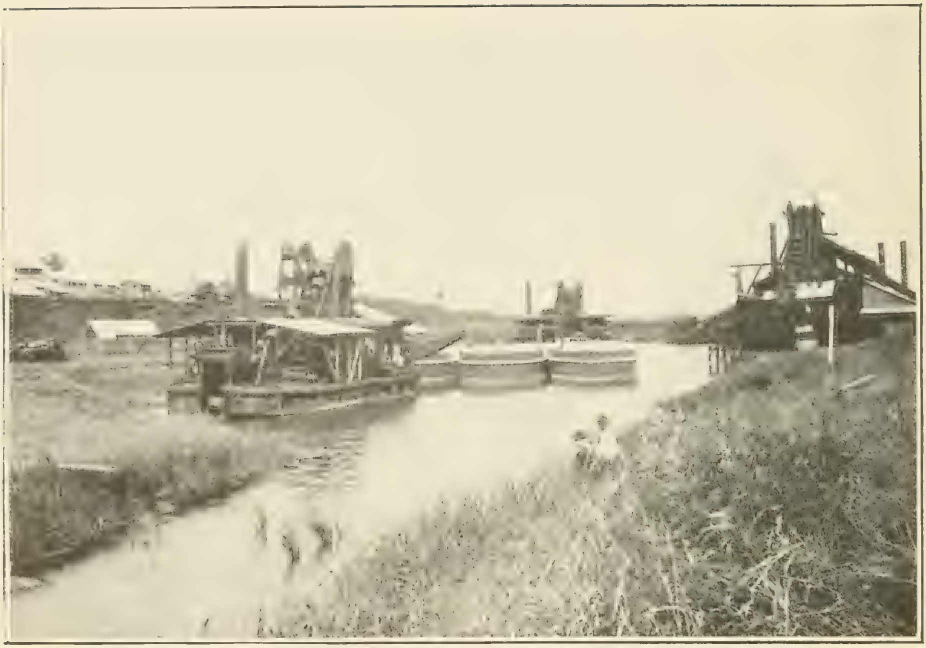

FIG. 1.—CUTTING THE CANAL THROUGH MORASSES, CHAGRES RIVER REGION.

FIG. 2.—THE CULEBRA CUT.

constructed should be a sea-level canal. A company entitled "Compagnie Universelle du Canal Interocéanique," and commonly known as the Old Panama Canal Company, was immediately organized to construct the work. After various efforts it financed the enterprise and began work, which was prosecuted until May 15, 1889, when the company went into bankruptcy, and its effects were put into the hands of a liquidator—an officer of the French court corresponding closely to the American receiver.

Prior to the bankruptcy of the old company the project for a sea-level canal was temporarily abandoned in the hope that the funds available might be sufficient for the construction of a lock canal. After various vicissitudes the new Panama Canal Company was organized on the 20th of October, 1894. Work was resumed on the canal immediately thereafter, and has been continued until the present time, the force employed, however, being small. The old company raised by the sale of stocks and bonds not far from $246,000,000, and it has been stated that the number of persons holding the securities was over 200,000.

When the concession for building the Panama Railroad was secured from the Colombian Government, control of all available transportation routes across the Isthmus in the territory of the present Republic of Panama was covered by it. The construction of the ship canal by the old Panama Canal Company was, therefore, subject to the rights conveyed in the Panama Railroad concession. In order to control this feature of the situation, therefore, the old Panama Company purchased nearly the entire stock of the railroad company, which thus became a part of the assets of the new Panama Canal Company.

RECOMMENDATIONS OF THE ISTHMIAN COMMISSION.

When the Isthmian Canal Commission made its first visit of investigation of the canal routes four years ago, it found a large amount of excavation and other work done along the line of the canal, as well as a large amount of land, buildings, structures, and many plans and papers, all constituting a part of the property of the new Panama Canal Company. All this property was situated on the Isthmus, except a mass of plans and papers in the office of the canal company at Paris. The Commission, in its report under date of November 16, 1901, recommended, in case of selection of the Panama route, payment of $40,000,000 to the new Panama Canal Company for all its property, rights, and concessions connected with the unfinished canal. That offer, as made by the United States Government, has since been accepted by the French company.

The Isthmian Canal Commission adopted the French line for its estimates, but made some material changes in the plans for the work. The canal as planned by the Commission is a lock canal, its typical or

standard section for firm earth having a bottom width of 150 feet, a minimum depth of water of 35 feet, and a top width of 269 feet. This section is suitably modified for harbor sections, for sections in soft ground, for sections in rock and in lakes and wherever required by unusual conditions. These adopted sections would afford ample waterway for the greatest ships afloat at the present time, as required by the law creating the Commission.

The locks for this canal are great masonry constructions, having a usable length of 740 feet with a clear width of 84 feet, more than large enough to accommodate any vessel now afloat or planned to be built.

Beginning at the 6-fathom curve in the harbor of Colon, the canal is planned to be excavated for a distance of 7 miles through the low, marshy grounds in that vicinity to Gatun, where the line meets the Chagres River. From that point to Bohio, about 17 miles from Colon, a little east of south from the point of starting, the canal would be excavated generally along the marshy lowlands through which the Chagres River flows in that vicinity, cutting the course of that river four or five times. This 17-mile section of the canal is a sea-level section, but at Bohio is found a comparatively narrow place in the valley of the Chagres River with rock outcroppings on one side and at which a dam may be built. At this point it was the purpose of the French company also to build a dam, but the Isthmian Canal Commission provisionally located its dam at a site nearly half a mile downstream from that of the French dam, and proposes to build it materially higher.

GREAT DAM AT BOHIO.

This dam would retain behind it the waters of the Chagres River at an elevation varying from 85 feet to 90 or 92 feet above mean sea level, thus forming what has been called Lake Bohio. It would back up the water of the Chagres River for a distance of about 20 miles, through about 14 of which the course of the canal would be laid. Lake Bohio would constitute the summit level of the canal, and would be reached by two great masonry locks built together, i. e., in series near one end of the dam at Bohio, the lift of each one of these two locks being 45 feet as a maximum. These locks would be built as twin structures, so that if an accident should happen to one side the other side would still be available for use, and thus save the operation of the canal from being broken. A great ledge of rock affords an excellent site for the construction of these locks.

The building of this great dam at Bohio, with its top nearly 100 feet above the water in the river in its normal condition, is one of the great works of the entire canal construction. As the safety and operation of the canal would depend entirely upon the stability of this

dam, the Commission recommended a plan of construction by which a masonry core wall 30 feet thick at the bottom and 8 feet at the top would be built up from the rock beneath the bed of the river to the top of the dam, thus efficiently preventing all leakage of water through the porous sand and gravel, of which large portions of the substrata beneath the river bed are composed.

As the top of this dam would have an elevation of 100 feet above the sea, and as the highest water in Lake Bohio would be 8 feet lower than that elevation, no water would ever overflow this dam, but the surplus of flood waters of the Chagres River would be discharged over a masonry spillway about 3 miles from the dam. The spillway weir would be of masonry and about 2,000 feet long. Its location is in a notch or depression in the ridge between the headwaters of a small tributary of the Chagres called the Gigante and the valley of the Chagres River. The crest of this 2,000-foot-long overflow would be 85 feet above sea level. It is estimated that with the greatest flood possible in the Chagres River the depth of water on the overflow weir would not be greater than 7 feet. During a great flood, therefore, the river would discharge into this lake, and its waters would accumulate there until deep enough to run over the masonry spillway. With the flood in a rising stage, the amount flowing over the spillway would increase up to the greatest flood height, after which the rate of discharge over the spillway would decrease. This regulation of the Chagres floods, therefore, takes care of itself. It requires no attention. After discharging over the spillway, the flood waters would flow through an artificial channel down into the Chagres River beyond any of the canal works and where no damage would be done.

About 10 miles up the Chagres from Obispo, at a point called Alhajuela, there is an excellent site for a dam. It has been proposed to build at this Alhajuela site a great masonry dam for the purpose of impounding flood waters of the Chagres River to the extent of the storage capacity behind the dam, and so reduce the flood effects in Lake Bohio. This storage reservoir would also act as a source of feed water for the canal, should the traffic on it in the future become so large as to require this additional supply.

CULEBRA CUT.

From Obispo, 30 miles from Colon, the canal line runs toward the southeast through the continental divide in a direct course toward Panama, and for nearly 7 miles from Obispo a great cut has to be made through the high ground forming that divide. For a distance of about 5 miles from Obispo this is known as the Emperador Cut, beyond which lies a mile and a half known as the Culebra Cut. The greatest depth of this cut at Culebra is about 250 feet, and the amount of material to be removed in this stretch of 7 miles of canal excava-

tion is about 43,000,000 cubic yards. It is the greatest single feature of the entire canal construction.

The summit of Bohio Lake level ends at a point called Pedro Miguel, about 1½ miles southeasterly of the Culebra Cut and 38 miles from Colon, where is located a flight of two locks arranged in twin plan like the others, each one of the pair having a lift varying from 27 to 31 feet, according to the varying height of water in Lake Bohio. By means of these two locks the water surface in the canal is brought down to an elevation about 28 feet above sea level. The last lock on the line is at a point called Miraflores, a little less than a mile and a half from the Pedro Miguel locks. From Miraflores to the end of the canal, at a point called La Boca on the Bay of Panama, is less than 5 miles, and this portion of the canal constitutes what may be called the Pacific section or level.

The water of this Pacific section of the canal rises and falls coincidentally with the tides in the Bay of Panama, and as the range of tide in that bay is about 20 feet, the Miraflores lock is largely a tidal lock. Its minimum lift, therefore, at high tide, is 18 feet, while the maximum lift at low tide is 38 feet. It is obvious from these tidal conditions that if the canal were constructed as a sea-level canal a tidal lock would be needed at or near its Pacific end. That part of the canal line between Miraflores and the Bay of Panama is located closely along the course of the Rio Grande, which is mainly a tidal river, its two principal tributaries above Miraflores being Rio Pedro Miguel and Rio Caimitillo, both being small and insignificant streams.

The length of the canal between the shore lines is about 44 miles, although the length between the 6-fathom curves on the two sides of the Isthmus, as has already been stated, is 49 miles, 13 of which lie in the artificial Lake Bohio. The creation of Lake Bohio would necessitate the relocation and rebuilding of the railroad between Bohio and Obispo, throwing it back upon higher ground.

No canal with locks can be operated without provision for the water used in taking boats through the locks, for evaporation, for seepage, and for other purposes incident to the maintenance and operation of the canal. At each lockage on the Panama Canal a lock full of water, representing a volume nearly 750 feet long, 84 feet wide, and 45 feet deep, would be used in the Bohio locks and about two-thirds as much in the Pedro Miguel locks. This requires a large supply of water, which the Isthmian Commission computed for all purposes to be 1,070 cubic feet per second for an annual traffic of 10,000,000 tons passing through the canal. This water supply is afforded by the Chagres River, and without it or its equivalent the canal would not be possible.

In view of the complete system of self-control of the Chagres floods by the Gigante Spillway, the Chagres River, instead of being an insurmountable obstacle to the construction and maintenance of the canal,

as has at times been apprehended, is actually a gracious feature of the canal environment, and by that automatic control it has been changed from a sinister agent to a friendly power. Furthermore, while the average discharge of the Chagres River is nearly three times the quantity required for feeding the canal, there are times in the dry seasons when the discharge of the river is not more than two-thirds of the quantity required for that purpose. This deficiency is abundantly made up by the storage in Lake Bohio until the traffic exceeds 10,000,000 tons annually. At that time the storage in the Alhajuela reservoir will give an additional supply for an increase of traffic three or four times as great as the volume which can be accommodated by the storage in Lake Bohio.

ABOMINABLE SANITARY CONDITIONS.

The sanitary conditions of the Isthmus are at the present time wretchedly bad. Neither Colon nor Panama has either a system of water supply or a sewer system. The water used in Panama for potable purposes is brought into the city in casks mounted on wheels and drawn by mules from some more or less polluted source outside of but near the city, or caught in cisterns from the rain water flowing from roofs during the wet season, or in some other crude and usually insanitary way.

There are a few drains in the city of Panama, constructed immediately under the surface of the streets, with little or no regard to grades. The water or sewage and decaying matter collecting in the low portions of these drains and remaining there under the high temperature of the climate make them far worse than no drains at all. The lack of care and proper disposal of household and other refuse creates the most unsanitary conditions imaginable. Those observations may be emphasized for the smaller towns and villages between Colon and Panama. As a consequence, yellow fever is probably always present, and at times assumes epidemic form. Malarial fevers and other similar diseases are also continually present under aggravated forms. These conditions, however, are completely remediable by means well known and available at the present time.

The entire Isthmus can be placed in a completely sanitary condition so that its healthfulness shall be assured by resorting to methods and means which have now become practically standard in the sanitation of cities and towns. It is absolutely essential that waterworks, supplying potable and wholesome water, be established for the cities and larger towns, and concurrently therewith there must be established suitable sewer systems with rational and sanitary disposal of sewage. All these results are now perfectly practicable of attainment without unreasonable cost or material difficulty. It will be imperative, however, that sanitary regulations be created, enforced, and maintained

with the rigor of military discipline. Under such reasonable sanitary conditions as it is entirely practicable to attain, and with proper quarantine regulations, there is no reason why the Isthmus may not be maintained entirely free of yellow fever or from other tropical epidemics.

COST OF THE CANAL.

The United States Government has entered into a provisional agreement to purchase the entire property of every description and the rights of the new Panama Canal Company for the sum of $40,000,000. The cost of completing the Panama Canal under the plan of the Isthmian Canal Commission is estimated by that Commission at $144,233,358. The sum of these two amounts—$184,233,358—represents the total cost of the construction of the Isthmian ship canal by this route, to which should be added such additional costs as are required to be incurred in securing the additional rights and concessions necessary to enable the United States Government to enter upon the Isthmus and begin the work.

The consummation of this great work is apparently close at hand. The creation of the Republic of Panama has solved the difficulties which had gathered about the negotiations of the requisite treaty, and it will probably be but a short time before this, the greatest engineering work of the world, will be undertaken and carried to completion. This achievement will not only create new lines of ocean commerce and stimulate some of the older lines into new life, but it will also bring the Atlantic and Pacific shores of the United States into much closer communication than before, thus strengthening those bonds of mutual interest and natural sympathy which lie at the foundation of best national life. In this part of the world's development the new Republic of Panama becomes the center of the material activities through which these great results will be accomplished, thus attaining the fruition of four hundred years of effort. She is to be congratulated in marking her entrance among the nations of the earth by opening the way to the attainment of this world improvement and giving the work the impetus of her national sanction.

THE RECLAMATION OF THE WEST.[a]

By F. H. Newell.

In charge of the Hydrographic Branch and Chief Engineer of the Reclamation Service, U. S. Geological Survey.

Congress, in the spring of 1902, following the recommendations made by President Roosevelt in his first message, took up the matter of the reclamation of the arid West and on the 17th of June, a day celebrated in American history, the President signed the bill known as the reclamation law, setting aside the proceeds from the disposal of public lands in thirteen Western States and three Territories for

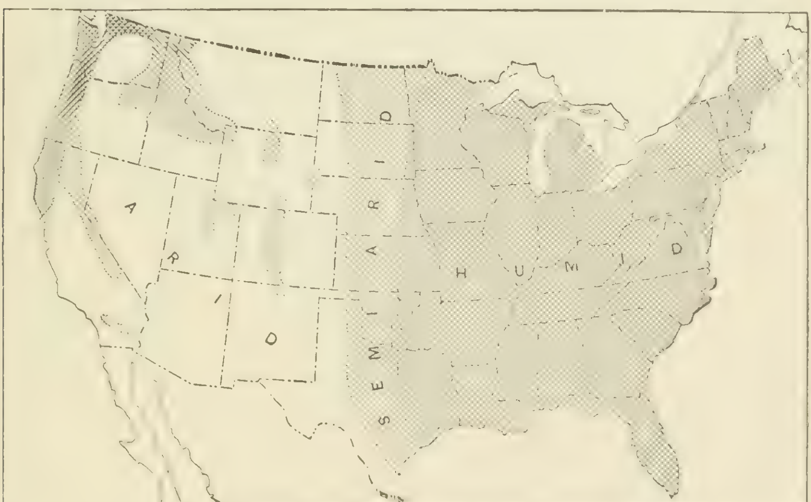

Fig. 1.—Map showing arid, semi-arid, and humid regions of the United States.

the construction of irrigation works. At that time the matter attracted little attention other than from those who were interested in the measure. It was thought to be simply a western scheme which had been successfully lobbied through against the opposition of the

[a] An address before the National Geographic Society, November 6, 1903. Reprinted after revision by the author, from The National Geographic Magazine, Washington, Vol. xv, No. 1, January, 1904.

leaders of both parties. As time has gone on the people of the country have begun to appreciate more and more the importance of the law not only to the West but to the country as a whole. It is now appreciated that if that law is well administered it will mean much to the future development of our country, and a complete change in some physical and economic features.

As geographers we are interested in the development of the country and in the changes that take place, and as citizens of the United States we are concerned in seeing that every resource is put to its best use, and that the country is developed to the fullest possible extent. The object of the reclamation law is primarily to put the public domain into the hands of small land owners—men who live upon the land, support themselves, make prosperous homes, and become purchasers of the goods manufactured in the East and the cotton raised in the

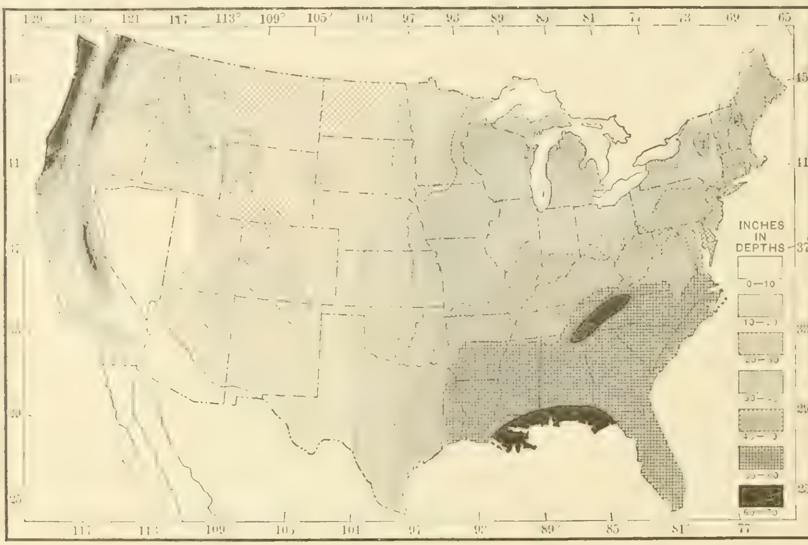

FIG. 2.—Map showing mean annual rainfall in the United States.

South. At the same time this is to be done in such a way that it will not become a burden to the taxpayers.

The money for the reclamation fund is from the disposal of public lands in the West. This money is returned again to the fund by repayment by the persons who are directly benefited. This matter of refunding is one of the most essential features of the law. Many considered this provision as trivial, but the more the effect of the law is studied the more thoroughly is it demonstrated that this repayment is one of the best safeguards of the law, keeping the administration clean and business like. The requirement that each project must be worth what it costs is a safeguard both in public and in private undertakings.

Attacks upon the law have been made under the misconception that the eastern farmer is taxed to make western farms valuable, and that the Government will be victimized by the lands passing into the hands of great corporations. These attacks would not be made if the men who utter them would read the law. It is carefully guarded in every respect, putting the lands into the hands of small owners and refunding to the treasury the cost of reclaiming the land.

This matter of irrigation and of western reclamation is by no means new. It has been discussed most thoroughly and persistently by one of our prominent members now gone before, John Wesley Powell. "The Major," as we all called him, in his early years made extensive explorations in the West, studying its topography, geography, geology, and ethnology. In the course of those researches he became

FIG. 3.—Map showing arid regions of the world—the humid regions shown in black.

greatly impressed with the great opportunities for development of this western arid land. He talked this matter in season and out of season, and many of his friends have said, "Now, Major, if you will only stop this irrigation talk we will do anything you want, but we can not have that." We are glad that he lived to see this law passed, and though it was not exactly on the lines he sketched in his original thesis, yet it follows his ideals. His report, written in 1876, is still one of the classics to which all refer.[a]

BROAD PROVISIONS OF RECLAMATION LAW.

The reclamation law is short and quickly read; its terms are general and it commits to executive discretion nearly all of the details which

[a] Lands of the Arid Regions, etc.

make a law a success or a failure. It sets up a few large and important safeguards, and says in effect to the Secretary of the Interior, "Here is this money; take it and spend it for this purpose; get it back in the Treasury and do the best you can with it." That is unquestionably the ideal condition, and the men who are working under it must make it a success. They have no excuse for a failure. Congress has been liberal, has given the Secretary wide discretion, and we have no apparent excuse for not obtaining the best results which the conditions will permit.

I have spoken of two or three of the large safeguards imposed, namely, the putting of the land into the hands of small owners who will live on it and cultivate it, and the refunding of the money to the Treasury, the money to be used over and over again in a revolving fund. When the law was passed the matter did not seem very important. The amount of money involved did not seem large and the opponents of the bill had little appreciation of the situation. It covered into the Treasury funds for the year 1901 and succeeding years, as follows: For 1901, $3,000,000; for 1902, $4,000,000 more, and for 1903 about $8,000,000; in all, now about $15,000,000. The fund at the present time is increasing rapidly.

THE RECLAMATION SERVICE.

The Secretary of the Interior, to whom the whole matter is committed, in commencing the work, decided to put it in the hands of a man and an organization in whom he had and has confidence. Hon. Charles D. Walcott, Director of the United States Geological Survey, is the man whom the Secretary holds responsible for this work. He in turn is assisted by several men who since 1888 have been measuring the streams of the West, studying the water supply, and making an examination to ascertain how the lands can be reclaimed by irrigation.

The Geological Survey has for years been making a topographic map of the United States, and on that map are shown the streams, the reservoir sites in or near the mountains, and many other facts which are essential to a practical knowledge of the subject.

In addition to the topographic branch, the hydrographic division has been measuring the waters which may be used or stored in these reservoirs. It was practicable at the beginning of the work to take experienced men out of the corps existing in the Geological Survey and to add to these from time to time, through civil-service examinations, men who are experienced in the actual construction and operation of irrigation systems. Now, there is an engineer corps of about 200 men, mostly young and active. A few have obtained age and maturity of judgment and will hold these younger men in check. The men are grouped in districts. At the head of each district is a man of experience who has been State engineer, as in the case of Idaho, or

has had large practice in irrigation work. To him are assigned men who have had more or less technical training. The plans made by these engineers are submitted to a board of consulting engineers, comprising men of wide experience and national repute.

The work extends over thirteen States and three Territories. These sixteen political divisions comprise the largest of the United States excepting Texas. Texas came into the Union as an independent republic, owning its vacant lands, and hence the land laws of the rest of the States are not applicable, nor is the law of June 17, 1902. All of the large western States are included. Thus the development of nearly half of the United States is resting upon the best execution of this law.

The problems are not merely those of engineering and constructing great works. It is not sufficient to build canals and bring the water where the people can get it; but, more than this, there are an infinitude of problems to be solved, and great tact must be used with people. When it comes to the question of dealing with water, men may be good citizens, but they can not be implicitly trusted when it comes to the question of water distribution. In Idaho they have the term "winter friendship." During the summer every man is at war with his neighbor over the division of water, but in the winter these troubles are forgotten and everyone is on friendly terms. Summer is the time of storm and strife in water affairs. So, in everything having to do with water and its distribution, engineers must have not only knowledge but good sense, tact, and firmness. To deal with the interests which are concerned in the distribution of water and the reclamation of land, it is necessary to organize the people into associations. These associations under the law must ultimately control and operate the works; through them the Secretary of the Interior can deal directly with a body of people, and they can divide the water among themselves and settle minor matters as best they can. The reclamation of the West is not only a scientific problem, but, for ultimate success, involves great tact and skill in administration.

THE PUBLIC LANDS.

The public lands are of many kinds, from densely forested areas extending far up on the slopes of the high mountains of the Rockies down to the vast low plains and wide spreading, trackless deserts. Particular interest is attached to these high mountains and the forested slopes, for upon these depend to a large extent the future prosperity and the utilization of the agricultural lands of the West.

The extent of the forests is shown by diagram 5. In northern California and along the Pacific coast in western Oregon and Washington are the greatest forests remaining in the United States. Around the

Yellowstone National Park and in the Rocky Mountain region in general are other important forests. In considering any question concerning the forests we must bear in mind that the word forest comprises a great variety of tree growth. In the East it usually means a dense growth. Out in Colorado or Wyoming you can sometimes see a half mile through what is called a forest. Thus, when we discuss forests on the public lands there must be some explanation of what kind of a forest we are talking about, if we are to be correctly understood.

FIG. 4.—Map showing location of vacant public lands.

A little scrubby growth of cedar or piñon may have great value to the pioneer, although it is not merchantable timber. These small trees furnish the poles and the posts which are so necessary to the settler. Even the small bushes and dwarfed junipers or mesquite may supply the fuel which he must have for his home.

The present distribution of the public lands is exhibited by diagram 4. In black are the lands which have been taken up by individuals.

Much of this public land is now used for grazing, but there are many thousand acres which with water will support hundreds of prosperous homes.

Examining the map it is seen that on the eastern edge the black dots representing settlements gradually thin out in western Nebraska, western Kansas, and eastern Colorado. Here is a vast extent of fertile but

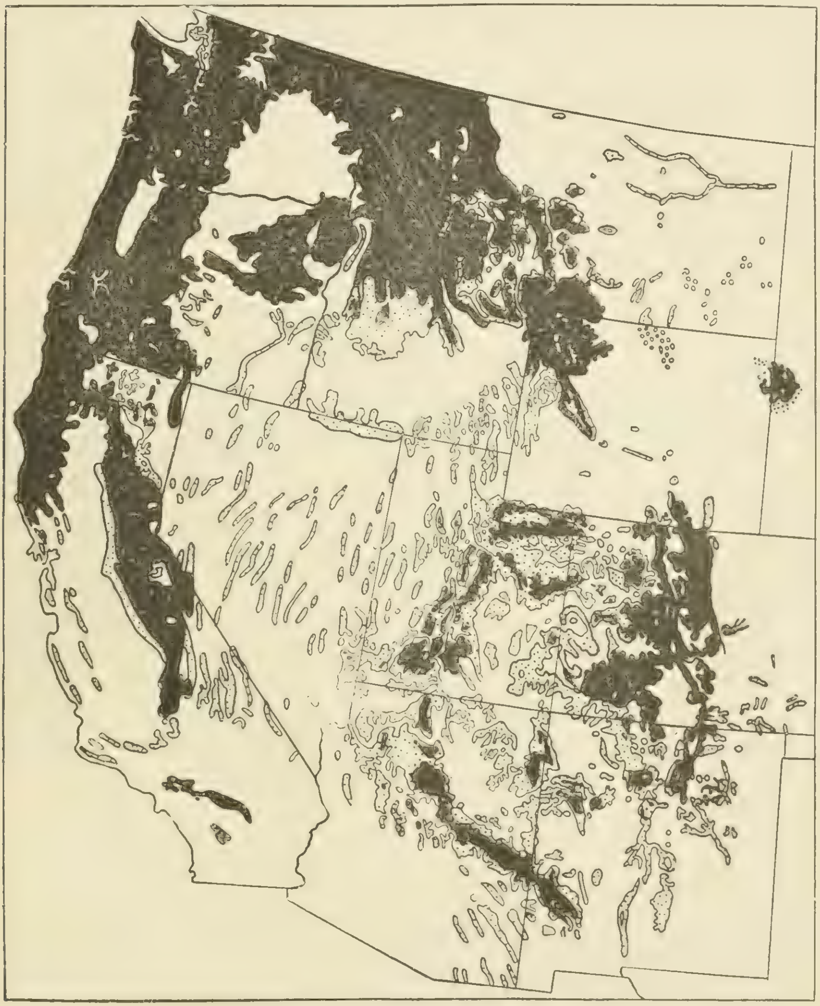

FIG. 5.—Map showing location of forests and woodlands of the West—forests in black, woodlands dotted.

dry country, where much of the land is in public ownership and the remainder is held largely by mortgage or loan companies in the East.

This wonderfully attractive and in many ways rich country may be called the famine belt. In it many attempts have been made, in

vain, to secure permanent settlement, and thousands of industrious and hard-working settlers have been forced to leave by starvation. This is due to the fact that the rains are erratic in character, and, on an average, are just sufficient to produce good crops. In one year, or series of years, large crops may be raised, and the report is widely spread that here is the "promised land;" no sooner has settlement been established than the rains decrease slightly, or come at the wrong season, crops are lost, and the settlers are forced to migrate.

This is also called the country of the "rain belters," the phrase originating from a popular belief that by the building of railroads, the stringing of telegraph wires, the breaking up of the sod, and by other human agencies the belt of permanent rainfall is extended westward. This popular delusion has ensnared many emigrants, and even now it is repeated by those whose hopes lead them to the belief that the rainfall is actually becoming more stable.

AREA WHICH CAN BE RECLAIMED.

The area of land which can be reclaimed by irrigation is relatively small. If 2 or 3 per cent of the vast extent of arid lands of the United States are ultimately reclaimed and put under cultivation it will mean a population in the western half of the United States almost as great as that now in the eastern half of the country. Figure 6 shows the areas where it is probable that irrigation can be carried on, or where it is now being carried on, and where it can further be extended. If the West is developed to the extent that all these patches indicate we will have a wonderful change in the social and commercial relations of the United States as a whole.

The comparatively regular distribution of these irrigable lands in each State is notable. The entire extent of irrigation development in each State is, of course, very small, but, if I am correctly informed, the proceeds from the small irrigated area in Colorado are already greater than from the mines.

The vacant lands of the arid West may be considered under three distinct categories: (1) The irrigable land, which always will be relatively insignificant as regards area, but of first importance as to values; (2) forested areas, where the land has relatively little value for agriculture, but is of great importance in producing perpetual crops of wood or timber, and in protecting the water supply—this area comprises probably from 10 to 20 per cent of the arid West; (3) the great body of arid land which would be productive with water, but for which an adequate supply can never be had—this includes 80 per cent of the entire West, and is commonly spoken of as "desert," although nearly every acre has some value for stock-raising purposes at one time or another.

The irrigable land is being utilized through individual or corporate enterprise, and through the reclamation law. The forested areas are being protected by the activities of the Bureau of Forestry, but there remain the great tracts of grazing lands whose proper handling and control is still a matter of doubt.

A thorough knowledge of the location, extent, and capabilities of this vast grazing area must be had, and on the basis of this knowledge wise statesmanship must be shown in either holding this land perpetually, under suitable regulations, as an open commons for grazing or of disposing of it to individuals in such a way as to form permanent settlements and to create the largest number of homes. The grazing problem is the third and last of the great public land questions, the one which is still unsolved, and which, when satisfactorily settled, will lead to increased prosperity for the entire country.

THE RECLAMATION FUND.

The reclamation fund comes from the disposal of lands in 13 States and 3 Territories, and the amount is widely different in the different States. The law provides that so far as practicable the amount shall be spent in the State where it originates, but in fact the available funds are almost always inversely apportioned to the needs of any one State.

From Nevada, the State having the largest opportunity for development, the amount of money is represented by a small amount, while from North Dakota there has come an enormous fund. In the latter State there is little possibility of general development by irrigation because of the difficulty of finding irrigable lands and an adequate water supply. North Dakota and Oregon and Oklahoma have large funds. In Oklahoma, with its subhumid climate, there is little need of irrigation, and in fact it is almost impossible to find any reclamation project of considerable magnitude in that Territory.

PRESENT RECLAMATION WORK.

Examinations leading to construction are being carried on widely. At the points where dams may be erected for water storage the foundations must be studied, and for this purpose diamond drills are used to ascertain the character of the bed rock. Work of construction has been begun in two localities—one in Nevada and the other in Arizona. In Nevada the work in hand is that on a canal to take water from Truckee River into lower Carson reservoir site. Lake Tahoe, at the head of the Truckee River, is the highest large lake in the United States and in many respects is an ideal reservoir site, and its waters, if wisely used, will go far to promote the prosperity of Nevada.

In California, over the State line from Nevada, are opportunities for water storage. In the mountains are little valleys in which water can be held. It is impossible for Nevada, as a State, to utilize these reservoir sites, as it can not go across the State line. The National Government is alone capable of doing this work.

A dam put across Carson River near its lower end will flood back the water and make an immense reservoir capable of supplying sev-

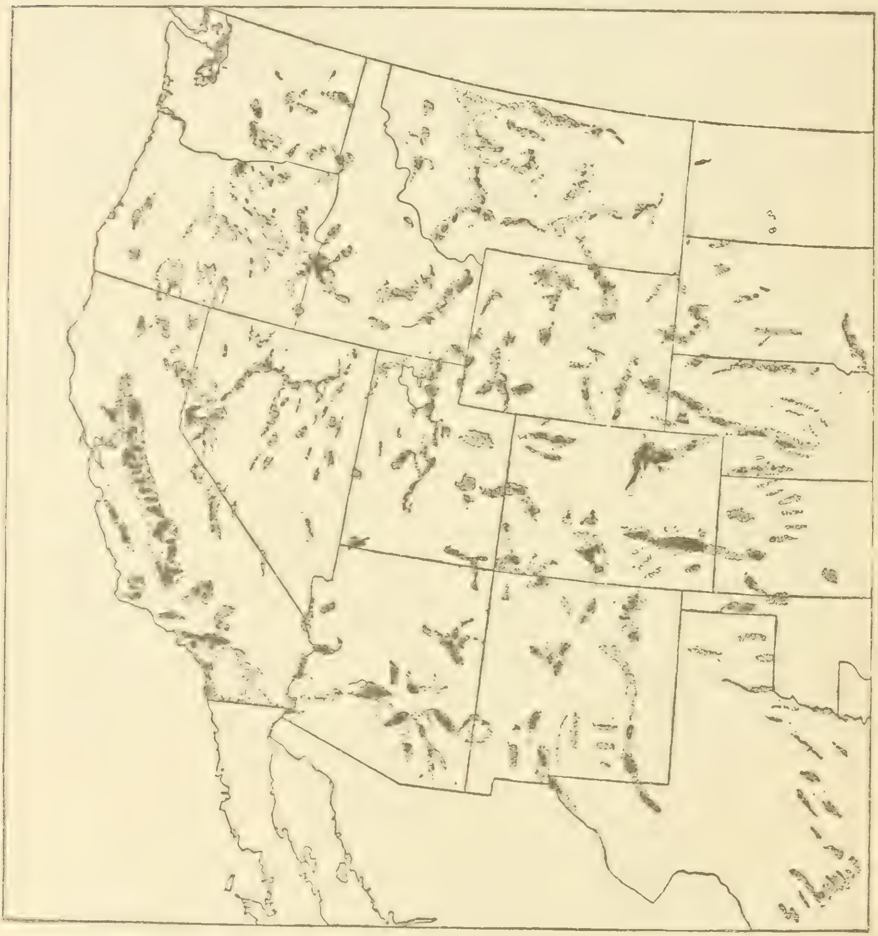

FIG. 6.—Map of irrigated and irrigable lands—irrigated areas in black, irrigable areas dotted.

eral hundred thousand acres of land which is now absolutely desert and almost impossible to cross.

The interstate character of these problems of reclamation is exceedingly complicated. The Rio Grande, rising in Colorado and flowing through New Mexico, forms the boundary between Texas and Mexico; the Arkansas rises in Colorado and flows through Kansas, Oklahoma, Indian Territory, and Arkansas; the South Platte and North Platte

flow from Wyoming into Nebraska; the headwaters of the Colorado rise in Wyoming and Colorado, flow through Utah, and form the boundary between Arizona, Nevada, and California. Nearly all the important rivers of the arid West rise either in Colorado or Wyoming, in the mountain ranges crossing these States, and flow out from these areas, furnishing water for adjoining States. This interstate character of the streams has been held as one of the reasons for Federal

FIG. 7.—Map showing approximate location and extent of open range in the United States.

The stock raising or grazing industry will always occupy 80 or 90 per cent of the arid lands of the West.

intervention in reclamation, as well as the fact of Federal ownership of the vacant lands.

In Colorado the largest project now in construction is that of taking the Gunnison River into the Uncompahgre Valley. This river flows in a narrow canyon 2,000 feet deep. This canyon has been regarded as impassable, but Mr. A. L. Fellows, one of the engineers of the reclamation service, and an assistant went through in 1902 at the risk of their lives. The attempt had been made a number of times to go down it by boats, but without success. These men did it

by means of swimming and by using a pneumatic mattress or rubber bed as a raft. They put in small rubber bags the necessary food and a little underwear. In ten days, by floating, swimming, and climbing, they succeeded in getting through and locating the point at which may be placed the headworks to take the water out by a tunnel into Uncompahgre Valley.

The tunnel, heading in the steep cliffs, passes under the mountain to the valley beyond, a distance of nearly 5 miles. Careful surveys and examinations are being made, and it is believed to be feasible to build the tunnel, if enough irrigable land can be found to justify the undertaking.

Another project which has been under examination is that in southern Wyoming on the North Platte River, at what is known as the Devils Gate, on Sweetwater River, a short distance above the point where it enters North Platte River. Unfortunately the amount of water available at this point is small, and after careful examination there is now being considered another reservoir site known as the Pathfinder, at a lower point, where there is ample water for storage purposes. This is on North Platte River itself, below the mouth of Sweetwater River.

The water stored in the Pathfinder reservoir in Wyoming will be turned down North Platte River to a point near Guernsey, where it can be diverted and taken out upon land in what is known as the Goshen Hole, in eastern Wyoming, adjacent to Nebraska. It is probable that the canals can be extended to cover broad areas in western Nebraska on both sides of the river.

In northern Wyoming there is another reclamation project, that on Shoshone River, which here flows through a granite range. Surveys are being made to demonstrate the practicability of diverting this river and carrying it out to the broad plains of the Big Horn basin east of the town of Cody.

One of the greatest works in the United States is the utilization of the great Colorado River of the West. The headwaters come from Wyoming and Colorado, flow through Utah and northern Arizona, and the river finally enters the Gulf of California. Along this stream are lands capable of high cultivation, as the soil is rich and the climate semitropical.

The rank growth on the bottom lands shows that wherever water is found the vegetation is extremely dense. It is, in fact, almost impossible to push one's way through this vegetation. The illustration shows some of the broad bottoms that can be reclaimed.

The river itself is constantly changing, shifting over a very broad extent of channel. Last Christmas a party of us took a trip down the river in a boat. We floated, paddled, and at times waded for 400 miles down that stream, under the most delightful climate in the

FIG. 1.—AN ABANDONED HOUSE ON AN UNIRRIGATED PLAIN.

The picture illustrates the impossibility of establishing homes on the public domain without first providing methods of irrigation.

FIG. 2.—ONE OF THE METHODS OF OBTAINING A WATER SUPPLY.

FIG. 1.—FLOATING THROUGH GUNNISON CANYON, USING A RUBBER BED AS A RAFT.

FIG. 2.—TOP OF TORRENCE FALLS, GUNNISON CANYON.

Attempts to go down Gunnison Canyon by boats having been unsuccessful, Mr. Fellows, an engineer of the reclamation service, and an assistant, by floating, swimming, and climbing for ten days succeeded in getting through and locating the site of the tunnel.

United States. It was a rare experience. We would be sailing under a good breeze at an exhilarating rate, and everybody would be gay, when suddenly we would slide up on a mud bank; then all would go overboard to tug and finally push off into deeper water, and then on until we brought up in another mud bank.

Plate IV shows where it will be possible to build dams similar to those built by the British engineers on the Nile. The river, although a quarter or a half a mile wide above, here becomes narrow, hardly wide enough for a steamer to pass, and at this point it would be possible to erect dams holding back the water. The great difficulty is the fact that the mud carried by the river would fill the reservoirs very rapidly.

Another project under consideration is in Arizona, on Salt River. This dam, if constructed, will be one of the greatest in the world, being 230 feet from foundation to top. The lands to be reclaimed along the Salt River are in the vicinity of Phoenix and are capable of a high degree of cultivation, producing crop after crop throughout the year. There are sometimes as many as seven crops a year raised.

In southern Idaho are vast tracts of desert land, to which water may be brought from Snake River. At the head of this river is Jackson Lake, situated at the foot of the Grand Tetons. By closing the outlet of this lake all the water can be held, storing a sufficient supply for tens of thousands of acres along Snake River, in Idaho.

Under present conditions the water supply in Snake River dwindles to such an extent that during the summer the channel is dry at points along its course. This river, which appears to be inexhaustible, is, as a matter of fact, nearly dry at points in eastern Idaho for several months when the water is most needed.

In a portion of the course of Snake River in southern Idaho it has been found practicable to divert the water upon vast tracts of fertile, level land. Here, near the railroad station of Minidoka, it is proposed to build across Snake River a substantial masonry dam and take out water on both sides with gravity canals, irrigating the sagebrush-covered plains. A large amount of water can be allowed to pass through or over the dam, and it is proposed to generate power, utilizing this to pump water to some of the higher lying tracts which can not be reached by gravity.

A great project under consideration is that of taking water out of some of the tributaries of the Columbia. Millions of acres susceptible of irrigation are below the level of the headwaters of Columbia River, but in order to convey these waters to the dry lands it is necessary to traverse mile after mile of steep side slopes. The cost of the project runs up into the millions of dollars; so that while the Government may execute it in the future, the project of reclaiming the great

arid lands of the State of Washington is one which is almost impossible for the present time.

In the region of the Black Hills of South Dakota and Wyoming are numerous small projects. Many streams flow outwardly from the hills through narrow canyons. By closing these gaps it is possible to hold water in various places around the Black Hills. Beyond are vast stretches of rolling country susceptible of reclamation. In the northern part of the region is one of the largest and best bodies of public lands to which it is practicable to take water. Here on Belle Fourche River are many thousand acres of public land which may be irrigated.

In New Mexico the problems of reclamation are quite difficult, owing to the character of water supply and the large extent of the old Spanish land grants, taking in much of the best land of the Territory. The principal stream is the Rio Grande, a perennial river in the northern part of the Territory, but in the southern part a dry, sandy channel throughout much of the year. Its waters must be stored, and to do this problems of silt must be successfully solved. In the eastern part of the Territory is Pecos River, a stream flowing through a vast extent of country underlaid in part by soluble gypsum, and here the construction of storage reservoirs is rendered difficult by the waters percolating through the gypsum and finding channels of escape through underground passages.

In Utah the central State of the arid region where irrigation development has proceeded very rapidly, the problems are extensive and far-reaching. The well-distributed streams coming from the mountains have enabled the Mormon farmers to build up extensive communities, but the small irrigating systems are not always economical of water, and there remains to put in practice a large, comprehensive system which, through better water conservation and distribution, will enable an extension of the irrigable area. Utah Lake seems to offer the greatest opportunity, for here, in this broad, shallow depression, four or five times as much water is lost by evaporation as is utilized in cultivating the soil. By reducing the area of this lake the extent of cultivated lands may be accordingly increased. Bear Lake, also on the northern boundary of the State, affords similar opportunities for conserving water.

In the far northern part of the arid region, in Montana, in the broad valley of Milk River, are opportunities of storing the short, intermittent floods of that stream. It is proposed to reenforce these, if practicable, by water held in the glacial lakes at the foot of the Rocky Mountains and put to use the streams which now flow northerly into Canada.

In Oregon, the Umatilla River, which flows into Columbia River, may be utilized by the construction of a large canal, catching its floods

"WE FLOATED, PADDLED, AND WADED 400 MILES DOWN THE STREAM, UNDER THE MOST DELIGHTFUL CLIMATE OF THE UNITED STATES."

There are many square miles of rich bottom land along the Colorado River capable of high cultivation if reclaimed.

RED CANYON OF THE COLORADO RIVER.

Where the United States may build a great storage dam, similar to the great dams at Assiut and Asswan in Egypt.

and taking them out into suitable basins where they can be held until they are needed on the broad extent of arid land south of Colorado River. In the eastern part of the State, on the Malheur River, are other localities where the floods may be stored and where thousands of acres of arid land can be converted into small farms sufficient to support a family in comfort.

The theory of reclamation is to conserve the flood waters that otherwise go to waste and hold them until such time as they are needed. There remains in the various States a vast extent of arid lands to which the flood waters can be carried and which, when watered, is capable of producing large crops and furnishing homes for prosperous farmers.

ROBERT HENRY THURSTON, 1839-1903.

ROBERT HENRY THURSTON.

By Prof. W. F. Durand.

The splendid legacy of material civilization which the nineteenth century has bequeathed to the twentieth is due in principal measure to the achievements of the engineer and the scientist, and among those whose names and influence are written large on the practice and the achievements of the latter part of the last century, the name of Prof. Robert Henry Thurston will hold an assured and abiding place. Success as a scientist or engineer is a complex result of many factors, natural capacity, industry, devotion to high ideals, persistence, faith, with some measure of opportunity. These and others might be specified, and all of them in high degree were joined in the character and personality of Professor Thurston.

Robert Henry Thurston was born in Providence, R. I., October 25, 1839; son of Robert L. Thurston, one of the pioneer steam engineers of the country. He spent much time in his father's engine works, Thurston, Green & Co. and Thurston, Gardner & Co., where he became acquainted with the engineering practice of the day, especially in relation to the design and construction of steam boilers and engines, and in general power-plant practice.

At the age of 16 he entered Brown University, where he graduated in 1859 with the degrees of Ph. B. and C. E., and later received from the same institution the degrees of A. M. and LL. D., and from Stevens Institute the degree of doctor of engineering.

He first entered business with his father's firm at Providence and was later their representative in Philadelphia, where he was located at the outbreak of the civil war in 1861. At this time, when the question of duty to country was pressing in upon the hearts and thoughts of all serious men, he decided early in the summer to offer himself for service in the Engineer Corps of the Navy, believing that in this branch of the national service he would find the best scope for his natural genius and personal tastes, and would furthermore thus be able to render service in which his previous experience might be of some ready value. In reply to his letter to the Secretary of the Navy he was ordered to report for examination to the naval examining

board, then in session at Philadelphia. This he did on July 9, 1861, and was in due course examined on July 25 and found well qualified for the naval service. His first commission as third assistant engineer, U. S. Navy, was made out under date of July 30, 1861, but it was not until about a month later, or on August 25, that he was called into active service and ordered to the U. S. S. *Unadilla*, fitting out at the Brooklyn Navy-Yard for service on the southern blockade. The ship was put into commission September 30 and sailed October 18 for Port Royal, S. C., where she was attached to the squadron under Rear-Admiral Dupont. After active service in these waters for about a year the *Unadilla* was ordered North to New York for repairs, returning again to her station in October, 1862. During the following winter the *Princess Royal*, a valuable merchant steamer, was taken as a prize, and due to the skill and valuable help rendered in connection with securing this prize, Assistant Engineer Thurston was ordered home in her, in charge of the engineer's department. The prize was taken North to Philadelphia, and after turning over his department at the navy-yard, Assistant Engineer Thurston was detached and ordered on February 11, 1863, to examination for promotion to the rank of second assistant engineer. This examination was passed successfully, and he was then placed on waiting orders, where he remained till the following June, when he was ordered to the *Chippewa* at Port Royal, S. C., in charge of the engineer's department. He remained on duty in this capacity for about a year, when the ship returned North to Philadelphia, and he was detached and placed on waiting orders. On July 11, 1864, he was ordered to the *Maumee*, which was fitting at the Brooklyn Navy-Yard, but a few weeks later was detached and ordered to the *Pontoosuc* for more immediate service, this vessel having been assigned to duty as consort to a Pacific mail steamer en route to Aspinwall and return. On October, 18, 1864, he was detached from the *Pontoosuc* and ordered to the *Dictator*, then fitting out and making preliminary trials in New York Harbor. This ship, containing machinery of Ericsson's design, had experienced great difficulty in meeting on trial the conditions specified in the contract, and it was feared that without extended change in the design and installation of the machinery she would be unable to satisfactorily meet the contract requirements. Assistant Engineer Thurston threw himself into this problem with his accustomed insight and zeal, and with minor changes and under his charge, the requirements were fulfilled to a point which formed the basis of a settlement satisfactory to the Government on the one hand and the designer on the other.

On June 6, 1865, he was ordered to examination for promotion to the grade of first assistant engineer, and received his commission as such the following month. Shortly after, the war being over, he was detached from the *Dictator* and placed on waiting orders, and in the

following December was ordered to the Naval Academy as assistant professor in the department of natural and experimental philosophy. He remained on this duty for the next five years, actively occupied in his duties at the Academy and in developing his invention of a type of magnesium lamp intended for use in a proposed system of military and naval signals.

In 1870 he was invited by President Morton, of Stevens Institute, to take part, as professor of mechanical engineering, in the organization of that newly founded educational enterprise. It was here that Professor Thurston, on broad and practically independent lines, first entered on his career as an engineering educator, and in which he won so large and enduring a place in the modern development of technical education. There were then existing no technical schools to serve as guides or precedents, especially in higher engineering work, and these early developments were largely pioneer in character. In all of the early work of organization and development Professor Thurston took a leading part as head of the department of mechanical engineering. He early organized a laboratory of mechanical engineering, the first of its type in the country, and thus sounded a new keynote in higher technical education. Now every technical school of approved standing has its engineering laboratory, and work of this character is yearly assuming an increasing importance in all lines of technical education. His early plans for such a laboratory were first published in 1871 and later amplified in 1875. In Europe work of this character had been inaugurated in a few institutions in 1870 and 1871, or only slightly earlier than the initial organization by Professor Thurston. He has said that the need of such a laboratory and of opportunities for such instruction had been strongly impressed on his mind when a boy in his father's workship, and during his entire career as an educator he gave much prominence to such work and much time and effort to the constant improvement and extension of the equipments of the laboratories over which he exercised supervision.

In addition to his work in Stevens Institute, Professor Thurston found time during these years to serve on several important commissions and juries. He was a member of a United States commission on boiler tests; was member of an international jury and United States Commissioner at the Vienna Exhibition in 1873, and edited the report of the commission on that exhibition, comprising four large volumes, and writing one of them, on manufactures, as his own contribution. He was also an active member of the American Society of Civil Engineers, and in the proceedings of that society reported frequently the results of his investigations on the strength of materials. In 1875 he was appointed member of the United States board for the testing of iron, steel, and other metals, and took for many years a leading part in the work of that board.

The tremendous drain of energy required for the work accomplished between 1871 and 1876 was more than his physical strength could safely be called on to furnish, and for the next three or four years he was in poor health, and on duty only a part of the time. In 1880, however, his health was again restored, and from that time for the next twenty-three years he enjoyed, in the main, excellent health, and lost no time due to serious illness.

In 1885 he was invited by the trustees of Cornell University to undertake the work of organizing and developing a college of mechanical engineering on the foundation provided by Sibley College, which had been founded at about the same time as Stevens, but had developed on less distinctively engineering lines. Professor Thurston brought to this work all his native enthusiasm and force of character, with the experience he had acquired during the preceding fifteen years in similar work at Stevens Institute. The results of the organization which he brought about, and of the new life which was thus instilled into the work of the college, were speedily seen in a general elevation of the quality of instruction and of the student body at large, and in a rapidly increasing number in attendance. On taking charge, in 1885, the total attendance in all classes was about 60, with a total teaching force of 7, while at his death, in 1903, these figures were, respectively, 960 and 43. Professor Thurston saw clearly the possibilities of a great engineering school at Cornell University and labored unceasingly for its development and perfection along these lines. In his ideal he included a system of schools of engineering and of the mechanic arts, offering in the fundamental departments expert instruction in the foundations of all principal departments of industry, and laying a broad foundation for successful work in all lines of industrial activity; joined with these a system of schools of the industries in which the use of the essential apparatus and equipment of these industries should be exhibited by expert teachers and discussed with reference to their fundamental principles and their relation to broader and more fundamental principles; again, a system of schools of the constructive professions of engineering, and then, correlated with all, a department of experimental research, in which the many problems which arise in these various lines of engineering and industrial activity might receive careful study at the hands of expert investigators, and wherein the student might gain that vital contact with the actual materials of engineering construction, and with the various mechanisms which he is to construct or employ, which alone can give him the actual knowledge that the successful prosecution of his professional work will demand.

Naturally, not all of this ideal has been attained. Lack of funds has prevented more than the blocking out of a part of the work, and that on broad lines, and in developing some few of the special lines which

seemed most timely. Sibley College as now organized, and as thus expressing the purposes of Professor Thurston so far as he was able to realize them, comprises a general line of undergraduate work covering the foundations and the broad middle ground of mechanical engineering work, together with three departments in which is given the essential characteristic instruction related to three special fields of engineering practice namely, electrical engineering, marine engineering and naval architecture, and railway mechanical engineering. Many other special branches had long been in the programme, but the necessary limitations of space and funds have so far prevented the extension of the development beyond the extent specified.

Throughout the eighteen years of his work in Cornell his own teaching was in the subject of thermodynamics and steam engineering and in the economics of power generation and of manufacturing establishments. In the first subject a required course was given for two-thirds of the year, while in the latter two elective courses were given during the remaining one-third.

His policy regarding organization was distinctively generous in relation to the various heads of department. He believed in giving to each head of department a large measure of independent initiative and in holding him responsible for results. Rarely did his supervision extend to any control over details of internal department administration, and thus each head was left to work out his own problems in accordance with his special environment and to administer his department in detail as he might judge best.

In addition to his regular work in the university, Professor Thurston found time while at Cornell to serve on several important boards, among them the New York State commissions on voting machines and on the selection of a firearm for the National Guard, and the United States commissions on postal-pneumatic service and on safe and vault construction.

He also made during these years his most important contributions to the literature of engineering, and in particular wrote his exhaustive works on the steam engine and steam boiler.

In addition to his books, Professor Thurston prepared and published a vast number of papers on a wide range of engineering subjects. His papers on the materials of engineering and on thermodynamics and steam engineering are especially numerous and important, and much of his best thought and effort has gone into the preparation of these monographs and shorter publications.

A list of his larger works, written both at Stevens Institute and at Cornell, shows that his activities may be grouped under three different heads. The first one of these is made up of works on the materials of engineering, the second of works on the steam engine and the steam

boiler, and in the third we find publications more purely philosophical, historical, and biographical.[a]

In the field of invention Professor Thurston has made several contributions to engineering art, the more important being lamps burning magnesium, navy signal apparatus, autographic testing machines for iron, steel, and other metals, testing machines for lubricants, and improvements in steam engines and in scientific engineering apparatus. He also did much work in scientific research and in the investigation of important engineering problems, among which may be mentioned:

The determination of the useful qualities of the alloys of copper and tin, copper and zinc, and copper, tin, and zinc.

Studies of boiler explosions.

Researches regarding the laws of friction and lubrication.

Laws of variation of engine wastes and studies in the economy of the steam engine.

Professor Thurston was a member of the leading engineering and scientific societies of this country and of Europe. He was the first president of the American Society of Mechanical Engineers and succeeded himself for the following term as well. He was three times vice-president of the American Association for the Advancement of Science, vice-president of the American Institute of Mining Engineers, and Officier de l'Instruction Publique de France.

Professor Thurston possessed to a remarkable degree the capacity for rapid and intensive work. This was due in no small measure to

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[a] The following is a list of the larger works, grouped as indicated above:

The Materials of Engineering, J. Wiley & Sons.

Part I.—Nonmetallic Materials of Engineering and Metallurgy.

Part II.—Iron and Steel.

Part III.—Alloys and Their Constituents.

The Materials of Construction, J. Wiley & Sons.

Treatise on Friction and Lost Work in Machinery and Mill Work, J. Wiley & Sons.

Stationary Steam Engines, J. Wiley & Sons.

Development of the Philosophy of the Steam Engine, J. Wiley & Sons.

A Manual of the Steam Engine, J. Wiley & Sons.

Part I.—History, Structure, and Theory.

Part II.—Design, Construction, and Operation.

A Manual of the Steam Boiler, Design, Construction, and Operation, J. Wiley & Sons.

A Handbook of Engine and Boiler Trials, and the Use of the Indicator and the Prony Brake, J. Wiley & Sons.

Steam Boiler Explosions in Theory and in Practice, J. Wiley & Sons.

History of the Steam Engine, D. Appleton & Co.

Heat as a Form of Energy, Houghton, Mifflin & Co.

Reflections on the Motive Power of Heat, J. Wiley & Sons.

Life of Robert Fulton, Dodd, Mead & Co.

The Animal as a Machine and Prime Mover, J. Wiley & Sons.

his powers of concentration and to an excellent memory filled as a storehouse, either with facts or with the location of facts and where successful search for them might be made. These powers joined to a sympathetic nature led him to cover an unusually broad field of activity with his professional writings, and to show an aggregate result of astonishing magnitude. It is not in his books and papers, however, that his chief monument is to be found, but rather in his direct educational work, and particularly in the organization and development of Sibley College, and in the men who have gone forth into the various fields of active engineering practice so largely indebted to him either for direct personal instruction or inspiration, or for the opportunities which came as the result of the organization and administration of the college under his direction.

Personally Professor Thurston was sympathetic, warm hearted, and optimistic, and an inspiring friend and leader. He was never discouraged by an appearance of failure and believed steadfastly that the great purposes which he was directing and which he was endeavoring to shape to his ideals would all one day work out to the best and highest uses of mankind. As a rule he was rapid in his judgments on matters of a scientific or engineering character, but when the human element was involved, and on matters of broad policy, he was more slow in forming a final judgment, but, once formed, was tireless in carrying it forward to realization.

Professor Thurston died suddenly on the evening of October 25, 1903, on his 64th birthday, in the midst of his great work in Sibley College, in the full possession of his normal strength and mental activities, and with apparently many years yet of fruitful labor before him.

While it may be too soon to estimate with exactness his place in the galaxy of the great minds which the nineteenth century produced, yet among those whose work adorned the latter part of this century the name of Robert Henry Thurston will have an assured and abiding place. As an engineer, a scientist, an educator, a writer, an investigator, an expert and counsellor, as a public servant in many capacities, and as a man and good citizen; all of these fields of activity have been enriched with his labors and with his unswerving spirit of devotion to scientific truth. He has left to the new generation a rich legacy in work actually accomplished and the example of a scientific man and engineer faithful and true to the highest principles and standards of life.

THEODORE MOMMSEN.[a]

By Emil Reich.

On November 1 (Sunday), at 8.45 in the morning, Mommsen died, and in him the world of erudition has lost one of its very greatest representatives. It is no exaggeration to say that what Joseph Scaliger was to the world of scholars at the end of the sixteenth and in the beginning of the seventeenth century Mommsen was to all the students of Roman antiquity in our own time. The name "Roman antiquity" must be taken in its widest sense. Mommsen made personal and independent researches into every aspect of Roman civilization, history, law, and private life. In a series of works, which already in 1887 counted 949 numbers, representing 6,824 folio pages, 1,402 quarto, and 19,319 octavo pages, the great scholar investigated all the problems of Roman political history, chronology, numismatics, law, religion, etc. In fact, of him it may have been said what with less justice was said of Justus Lipsius: "Felicem hominem, qui per ea quæ repperit quæ disposuit quæ scivit, et vixit antequam nasceretur, et ita natus est ut nunquam sit moriturus."

Mommsen's life was as simple, and with few exceptions as uneventful, as that of most scholars. He was born November 30, 1817, at Garding, in the Duchy of Holstein. His father was the vicar of the place and had destined him for the study of philology and law. From 1844 to 1847 Mommsen, aided by a stipend from the Berlin Academy, made an extensive archæological journey through France and Italy. In 1848 he received a call as professor of law to Leipzig. However, on account of his participation in the revolutionary movement of the time, he was dismissed from his post. Two years later, in 1850, he became professor of Roman law at Zurich, and in 1854 he taught Roman law at the University of Breslau. Finally, in 1858, he was appointed professor of ancient history at Berlin. Within a year or two before his death he continued to teach ancient history at the first University of Prussia, and he must, at the lowest calculation, have

[a] Reprinted by permission from Monthly Review, London, No. 39, Dec., 1903. pp. 74–84.

delivered over 10,000 lectures to the students of Berlin. In his married life he was eminently successful, and his very numerous children (he had 14, we believe) caused him no particular trouble. Recognized as the head of the great historical school of Roman antiquity in Germany, honored and venerated, not to say worshiped by sovereigns, princes, scholars, and men of the world alike, he passed the last thirty years of his life in a position of exceptional dignity and influence.

Even in his conflict with the Iron Chancellor he conducted his trial in person and with success. The courts finally acquitted him of the political crime imputed to him by Bismarck. He traveled extensively, and especially in the last twenty-five years of his life he developed a perfect passion for the hunt of manuscripts. Printed books seemed to have lost their charm for him. What delighted him was a manuscript. He was a very frequent guest at the Bodleian and the British Museum, at the Bibliothèque Nationale, and at the great libraries in Italy. Even manuscripts of the early Middle Ages—that is, manuscripts reflecting only the last dim rays of the sunset of antiquity—excited his interest in a very high degree; and the number of authors that he edited with the minutest care was very considerable. His mind was influenced chiefly by the aims and methods of the philologist and the attitude and ability of the student of law. Now that we may clearly overlook the whole career of that extraordinary man, it becomes more and more manifest that, although Mommsen is known to the general reader only or preëminently as the historian of Rome, as the author of a famous history of Rome, yet, on impartial and closer examination of the case, it will be found that Mommsen in reality had neither the passion nor the highest capacity of the historian proper.

His was the genius of analysis rather than of synthesis. He excelled in monographs very much more than in works putting together in their final expression a vast array of facts. This seems to be in utter contrast to the fact that Mommsen has published great treatises both on Roman public or constitutional law, on Roman chronology, and on Roman criminal law. However, applying to Mommsen the strictest measure of criticism, we cannot but see that every one of those great treatises is rather a collection of monographs than a work giving a direct and full insight into the working principles of Roman institutions. Mommsen classifies, shelves, labels, and numbers both neatly and well; he enlightens but little.

The danger of a man like Mommsen is the false impression under which thousands of scholars, and through them the general public, have been about the real problems and the real importance of Roman history. The massiveness of Mommsen's information, the mere bulk of the works he has published to almost the last day of his life, the tone of finality and strict formality pervading every line he ever published, has naturally engendered the idea that he has not only furnished

the vastest amount of material, but also the only method and the only guiding aperçus in the study of ancient Rome. It is time to say that while he has done the former he has not done the latter. He has, indeed, through the publication of the Corpus of Latin inscriptions, and similar very useful collections of material, very much increased our means of studying Roman history, more especially of writing more numerous books thereon. It is, however, equally true that his influence, the undoubted authority that he enjoyed both in and out of the Fatherland, has in a measure sterilized the study of the history of Rome. Thus in the last twenty odd years exceedingly few independent and elaborate works on the ensemble of Roman history have appeared either in England or on the Continent. The scholars of the world seem to be under the ban of Mommsen. To abandon his method, to doubt the essential correctness of his Roman constitutional law (*Roemisches Staatsrecht*) seemed, and still seems, to be not only impossible but indecent. In England, if we except a few short works, more particularly the brilliant and suggestive study on Roman history by Mr. T. M. Taylor, no attempt has been made to rewrite the history of the great empire-nation, which in so many ways is so essentially similar to the Britons. In fact, it is part of the irony of things that the English have so far devoted great attention and great industry to Greek history rather than to Roman, although they are, from the nature of their own history and modern constitution, less apt to seize and clear up the factors and powers that made Greece; while they are eminently adapted for clearing up some of the most difficult problems of the history of Rome. Using expressions somewhat untechnical, yet precise, we may say that Greek history ought to be written by the French, and Roman by the British. In modern Great Britain alone can we still see institutions, the essential identity of which with those of the institutions of Rome ought to suggest to Britons in the first place, or to such as are intimately acquainted with Great Britain, some of that insight into the real nature of ancient Rome without which all study of history is blind.

It is almost impossible for a German scholar living in Germany to find any of those modern analogies to events and institutions in Rome without which we moderns are absolutely excluded from a real knowledge of Roman history. Mommsen's Roman History has accordingly very much more charm than real insight. Mommsen was a great artist; his style, like that of a few other North German writers, is both compact and fluent, clear-cut, plastic, and packed with information. It flows on majestically and resembles one of the Roman aqueducts; perhaps in more senses than one. There can be no hesitation in saying that, as a mere piece of reading, Mommsen's history is by far the best book ever written on Roman history. Mommsen—who shared all the passions and ideals of the revolutionary period in

Germany, and who viewed Roman events in the light of the events he had lived to see in Germany in the forties and fifties of the last century—Mommsen was almost driven to write a Roman history both intensely interesting and essentially un-Roman. For the Roman world within the times of the Republic or in the times of the Empire was so utterly different from anything that had developed or grown up in Germany, that no diligence in research nor any philosophical effort of the self-sustained mind could enable a German to write up events utterly different in character and drift from those of his own country and time. It is well known how bitterly Mommsen has fallen foul of Cicero: how in the passages relating to the great orator and statesman Mommsen tried to excel in that Schnodderigkeit or caddishness with which great men of letters who were also statesmen have always been treated by the recluse scholar. Lord Bacon, Edmund Burke, Adolphe Thiers, and others are naturally hateful to the politisirenden Philologen, as Mommsen himself called them. No Frenchman or Englishman could have committed such an absurdity. Boissier in France and Professor Tyrrell in Dublin, the latter in his magnificent edition of Cicero's letters, the former in his exquisite book, Cicéron et ses Amis, have long shown the inaccuracy and falsehood of all that Drumann and Mommsen had said about Cicero.

Both the British and the French scholar had from the history of their own countries been well acquainted with historical types not unsimilar to that of Cicero. The German had no such type to enlighten him. And as in this case, so in cases of far greater importance. Take, for instance, Mommsen's historic judgment on the most important institution of Rome—on the tribunate.

It is well known that the tribunate is at once the strangest and the most important institution of ancient Rome. The strangest, because no modern nation has at any time thought of investing any magistrate, whether a pope, a king, a minister, or a judge, with powers as extensive, as comprehensive, and dangerous as the Romans did with regard to their tribunes. The tribune was enabled, if unchallenged by one of his nine colleagues, to stop any wheel of any part of the Roman State machinery. The senate as well as the assembly, the law courts as well as the religious institutions were, as it were, at the mercy of an irresponsible tribune. This, it must be admitted, is positively incomprehensible, and such of us as want to derive from the study of history more than a mere mass of names and dates, can not but approach the Roman history of Mommsen with the hope and expectation to find some reasonable explanation of the fact that the Romans, that is, an eminently practical and sober nation, permitted their tribunes to wield a power greater and more irresponsible than that commanded by even the mightiest pope of the middle ages.

This is how Mommsen disposes of the problem of the tribunate. He calls that institution a strange magistracy (seltsame Magistratur); and the introduction thereof he calls a foolhardy experiment (verwegenes Experiment) or a pis aller (Nothbehelf).[a] In other words, Mommsen disposes of the whole problem by sneering at it. In spite of the immensity of his studies of Roman constitutional law, he has never so much as approached the only question that is both interesting and instructive for us moderns. If the tribunate be so strange, abnormal, inorganic, as Mommsen, Schwegler, L. Lange, and all the other German writers declare it to have been, why then was it the only one of the institutions that even Sulla, in spite of the boundless power he wielded, did not dare to abolish? Why did the tribunate not become obsolete by the middle of the fourth century B. C., when the plebeians had obtained practically all the rights that the tribunes had been introduced to protect? To all this Mommsen does not vouchsafe us the slightest reply. The reason is that Mommsen, absolutely unacquainted with magistracies whose powers are remotely similar to that of an ancient Roman tribune, could not possibly rise to a real grasp of that central institution of ancient Rome. In England alone, of all modern countries, there has been in the last three or four hundred years a magistracy whose power and character are essentially that of Roman magistracies. The great difference between modern constitutions and that of the Romans is the simple fact that we moderns attach the greatest importance to and invest with the greatest powers the members of the national assembly, whereas the Romans attached the greatest importance to and invested with the greatest powers the incumbents of a few high magistracies. Or, to put it even more shortly, the whole Roman constitution was based on personality. In England alone we find a similar principle at work, not indeed in every department of the British constitution, yet in the department of law. Law in England, that is, common law, was intrusted to a few great judges who both administered and made it. When in the times of the Tudors, and probably before them, the incumbents of those great law offices abused their powers, it became natural to check and combat them by the introduction of a counter judge, likewise invested with unbounded power. The power of the justices of common law being purely personal and practically irresponsible, it became inevitable to check them by the establishment of the lord chancellors as judges, who likewise created the law of equity of their own good will, and practically without any responsibility. Lord Ellesmere, chancellor under James I, "plainly claimed power to determine new cases on new principles, even against the law, and to legislate on individual rights." (Kerly, D. M., "Historical Sketch of

[a] R. G., p. 276 (8th edition).

the Equitable Jurisdiction," p. 96.) The same relation, then, that we can follow and observe between the lord chief justices and the lord chancellors in England; the same relation was on a wider scale and more comprehensively that of the tribune to the other magistracies in Rome. Just as the chancellor was the natural complement and check to the lord chief justice, and not an abnormal or inorganic institution in the system of English law; just as John Selden's (perhaps good-natured) sneer at the chancellor's law is based on a total misconception of the real and inevitable function of that English magistracy, even so Mommsen's sarcasms and sneers at the Roman tribunate only prove his total misconception of this the most important institution of ancient Rome. The tribunate, far from being "abnormal" or "inorganic," "strange," or a "pis aller," was the most natural, the most organic, the most inevitable of all Roman institutions. It stood in the domain of Roman public law in the same relation to the other magistracies as does in the domain of Roman private law a res facti to a res juris; or as does in the system of Roman private law the interdictum to the actio, or any Prætorian legal institution to an institution of the jus civile.

On taking a broad view of Roman history and assuming, as all of us do, that a study of that famous nation ought to be not only attractive but also instructive, we soon see that there are especially three points in Roman history that appeal more particularly to our interests. These points are, in the first place, the marvelous political and military success of the Romans, in virtue of which they became the conquerors and rulers of an empire such as had never been before and has never been after—an empire consisting of the most civilized nations in the world; secondly, the surprising fact that the Romans, who held trade and commence in disdain, should have succeeded in building up a system of law which, especially in its sections dealing with trade and commerce, has proved to be of the same surpassing excellence that we admire in Greek art; and, thirdly, the Roman political constitution, which both from the success of ancient Rome and from the imitation of that constitution by the mightiest body politic of mediæval and modern times—by the Catholic Church—calls upon our closest attention and awakens our deepest interest.

If, now, we turn to Mommsen to obtain from him light on these three subjects, we are disappointed in every one case. The problem of Roman law he dismisses with another sneer, saying, literally, that there is nothing amazing in the fact that "a sound nation had a sound law," although he himself points out that the Romans did not excel in criminal law, in spite of their "soundness." As to the second problem, the military and political success of the Romans, we derive little, if any, light from the treatment of Mommsen. We still stand before the Fortuna Romanorum as before the Sphinx, and we do not even

know whether the decrepitude of the nations conquered was not greater than the fortitude of the Romans. We are still ignorant of the strange connection of facts which permitted every single nation of antiquity to defeat the Romans in more than one pitched battle, and yet in the end be compelled to submit to the Roman yoke. We still inquire wonderingly into the great problem why the Romans alone not only transmitted their own idiom to the conquered nations, but also rapidly promoted what the Greeks or Byzantines in the East could never do—the rise of neo-Roman languages.

When at last we try to obtain some real insight into that Roman constitution which Mommsen in his series of volumes has tabulated, formulated, classified, and systematized, we get from him indeed a number of useful schedules similar to the official lists or annuaires published by modern governments, enlivened by much juristic and legal formulation. It is not denied that the Roman officials and magistracies may rightly and legitimately be formulated from juristic standpoints, such as we apply in canonical law to the officials of the Catholic hierarchy. The juristic person of a bishop or an archbishop is a great, important, and interesting subject. However, it is equally certain that the most refined legal systematization of the Catholic or the ancient Roman hierarchy or magistracy does not advance us at all with regard to a true insight into the historic life and political drift of those officials. What is wanted is historic systematization, and not juristic. It is like in church history—we must not mix up dogmatics with church history. What Professor Mommsen has done to Roman constitutional history is precisely what his colleague, Harnack, of the Berlin University, has done to the history of Christian dogmatics. While Harnack's work is deeply engaging and learned, it advances only little our insight into the church history proper. Mommsen's book would have been an inestimable manual for the officials of the first century of the Roman Empire, but it does not help us very much in the comprehension of the Roman constitution as a product of living history.

The preceding remarks, no doubt, appear both harsh and ungrateful. However, a little further consideration will show that it is, we take it, necessary to say, and to say very frequently, what many a serious student outside Germany has long felt to be the case. We mean the overestimation of German Wissenschaft, of German methods of research, more especially of German ways of writing history. This overestimation is not likely to be felt as such unless it is shown up, especially in cases where German scholars have done real and great services to the interests of knowledge. The greater the real merit, the greater the danger that the merit will be exaggerated. Just because Mommsen has done so much, and has laid all students of Roman history under an obligation hard to overrate, we must

try to get at a just appreciation of his more constructive work, of the thought of his historical work, lest by considering it in the same light of unconditional admiration as we do his work as a collector of material we fall into an unjustifiable attitude of uncritical adoration. The Germans chiefly lack what many a British and French scholar is amply provided for—experience with the realties of life. If it be true that knowledge in the first place must come from our senses, although in the latter stages our sense impressions are worked up to concepts, it is undeniable that of past events, such as Roman history, we can no longer have any sense-impressions proper.

The only way to replace those impossible sense-impressions is to study modern and contemporary institutions rather than events that have a real and essential analogy with those of ancient Rome. By the careful selection and study of those analogies alone we may hope to derive suggestions if not solutions toward a right and living understanding of Roman institutions. The Germans being practically excluded from this, the only method of supplementing the study of the Roman and Greek sources and of arriving at a true comprehension of ancient history, we can not possibly admit that their innumerable theses, monographs, essays, handbooks, etc., advance our real knowledge of Roman history beyond what any British historian might very well do by selecting and studying carefully the undoubted analogies in British life and in the British constitution with Roman life and the Roman constitution. Surely we are all grateful to Mommsen and his rare idealism, his combination of the charms and power of the artist with the learning and indefatigable industry of the true scholar, are models for all the world, especially for the younger generation. On the other hand, it is impossible to suppress a voice of warning against the overestimation of methods of historical study, of which Theodore Mommsen has been the most illustrious representative, and which, we hold, increase the number of books of a purely archæological interest rather than augment the amount of real historical knowledge.

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